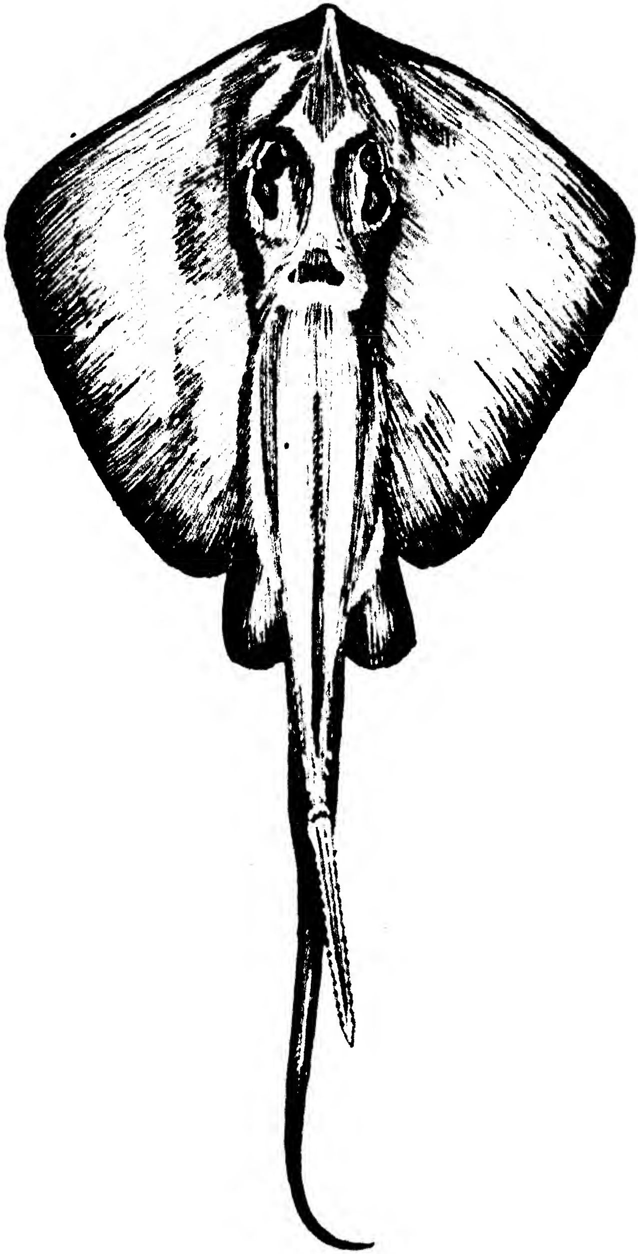

Fig. 1. The Sting-Ray (*Trygon pastinaca*)
(After Couch. One-tenth natural size)

Sting-fish and Seafarer

by

H. MUIR EVANS

with drawings by

IRENE HAWKINS

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TO
MY WIFE

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FOREWORD

It might appear to many people that a book with this title would be both dull and unnecessary; if however their inquisitiveness overcomes their initial prejudice, they will wonder still more why such a book had never appeared before. Many of the facts and incidents related can be found in periodicals and scientific literature, but a great part of this work consists of observations, which if not new, are unrecorded, and of researches both new and original. The marshman's remark: 'Eels is nothing only water vipers, though the big uns are more like sarpints,' contains a measure of truth, and is even more apt when applied to certain fish unrelated to eels. It will be found that there are many fish with all the dangerous attributes of snakes, and further that their venom may be either of the viper or cobra type, affecting chiefly either the blood or the nervous system. It is obvious why the deadly bite of the snake should have been the subject of much scientific research, but it is not so clear why the utility stings of bees and wasps should have been so often the subject of interesting studies, while the nature of the stings of venomous fish should have been neglected. This book will, I hope, prove very useful to fishermen, sea-anglers, and the nature-lover of the sea-shore, and also may be of interest to the general public, especially those whose job leads them to tropical waters. The injuries produced by venomous fish are always acutely painful and may result in crippling disablement or serious illness, but can be relieved or averted by suitable treatment, which should be more widely known. During many years I have had exceptional facilities which enabled me to carry on my researches,

especially as regards the supply of material; I have also been helped in many ways by the staff of the Marine Laboratory of the Ministry of Agriculture and Fisheries[1], particularly by the Director Dr. E. S. Russell and Mr. Michael Graham. But in search of material I have made fairly extensive travels. Starting from Bergen, I recall Scheveningen and Terneuzen, and from there I have taken my cruiser to Nieuport, Dunkirk, and Calais; at other times I have watched the French fishermen from St. Malo down to Roscoff and Douarnenez. The Mediterranean ports from Malaga to the French and Italian Rivieras have been my resort on many holidays, spent among their fishermen, while a prolonged stay at Madeira enabled me to get many specimens of abyssal fishes. My tropical experiences have been obtained mostly in Mauritius and on the Madagascar coast at Tamatave.

I should like to mention here my grateful thanks to Mr. J. R. Norman for his advice and help and to Mr. Adrian Bell for valuable suggestions.

[1] At Lowestoft.

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Chapter 1

THE WEEVERS

Trachinus vipera and *Trachinus draco*

'There shall no evil happen unto thee
that thou hurt not thy foot against a stone.'
'Thou shalt go upon the lion and adder;
'The young lion and the dragon shalt thou
tread under thy feet.'

I quote these verses from the 91st Psalm because there is some reason to believe that this is the only mention of stinging fishes in Holy Writ. The Psalmist apparently mentions three animals and a mythical dragon. It seems curious that he should have connected a young lion with the dragon, and further why should he associate the lion with the adder? It also seems strange that a lion should be trodden under foot. However if the verse be assumed to refer to fish the whole passage forms a metaphorical picture. Let me explain that the Lion-fish is another name for the Scorpion-fish and the adder is for the adder weever or viper weever and that the dragon stands for the dragon-fish (*Trachinus draco*), the greater weever. All of these fish are inhabitants of the Mediterranean Sea and all lurk under stones, and all are stinging fish with poison organs, and all are mentioned together in the earliest writings. For instance Apollodorus (about 300 B.C.), physician and naturalist, is known from his study of poisons and venoms and wrote a book on *Stinging and Biting Animals* which has become a book of reference for all subsequent writers on this subject.

Fishermen are liable to tread on these fish with their naked

feet, but if they catch a weever or scorpion-fish they crush it with their boot. The Weevers, the greater and lesser weever (*Trachinus draco* and *T. vipera*), are common coastal fish in British waters, the smaller being confined to coastal areas. Sir Thomas Browne, writing on the fish of Norfolk, mentions the adder-weever and in his quaint phraseology says 'a sting-fish, wiuer, or kind of ophidion or Araneus, slender narrow-headed, about four inches long, with a sharp prickly fin along the back, which often venomously pricketh the hands of fishermen'.

The Scorpion or Lion-fish is represented by the common Father-lasher or Sting-fish (*Cottus scorpio*) which also inhabits shallow water and is much dreaded by fishermen. It prefers however rocky bottoms to sandy shores. In appearance it is not unlike the freshwater Miller's thumb.

But stinging fish are not confined to the Norfolk coast and they are known to frequent the same grounds as shrimps—in fact, it might be said, where there is a shrimper there is a weever; and I might almost add that where there is a paddler there may be a weever, so a warning note may be sounded to parents and those in charge of children at the seaside. From my childhood onward I have always lived with people interested in the sea and those that go down to the sea in ships, and for my own part have always been interested in all that moves in the waters, in 'fishes and quaint monsters to which all that is terrible on earth',

> *Be but as buggs to frighten babes withal*
> *Compared with the creatures in the sea's entral.*

This is not mere poetic licence, but in the course of our search for these veritable dragons of the sea, we shall visit tropic seas and frozen fjords and explore abysmal depths.

My grandfather was the last of a line of clergymen who had held benefices in the diocese of Canterbury, since the end of the seventeenth century. His predecessors had been successive rectors of Headcorn, but he himself was the last incumbent of

Reculver and was also perpetual curate of Hoath. In the beginning of the nineteenth century the ancient church of Reculver was pulled down by vandals who turned the vicarage into a public-house, and two Roman columns were sold to a local farmer for stone rollers. But the twin towers known as the Sisters were preserved by the Trinity House and are still in use as beacons; these towers are immortalized in the Ingoldsby Legends,

There the twins stand on the edge of the land
To warn mariners off the Columbine Sand.

Shortly after the last war I had a close acquaintance with the Columbine Sand: in my six-ton sloop, my skipper and myself were beating up the Overland Passage towards Sheppey when the weather got worse, so instead of pushing on to make Queenboro', as we had hoped to do, we decided to anchor close to this sand, as advised in the sailing directions. The weather worsened and by the next morning a nasty sea had got up and we began to drag. We don't ask for trouble, but *Victoire* can stand a lot of knocking about, so we decided to snug her down and beat round to Queenboro'. While getting under weigh a Whitstable oyster-smack bore down towards us, hailing us: 'Can we take you into Whitstable?' Neither I nor my man were taking any, and old Nestling, a retired master of a drifter, and regular chapelgoer, replied 'We go~~e~~s where we want~~s~~ t~~o~~, we don't want none of your blooming help'. This forcible reply showed our appreciation of the aim of our kind-hearted fishermen to succour the distressed amateur, and reap a colossal reward in salvage money. But to return to my grandfather, he was like many other country clergymen, a scholar. He travelled and wrote a book which seems to have been widely read, *The Classic and Connoisseur in Sicily and Italy*. My copy in three volumes in solid calf binding was a gift to an Eton boy by his house-master on leaving, and from internal evidence it appears to have been more of an ornament to his bookshelves than a companion of his leisure hours. Besides being a writer, he was

a very considerable linguist, and as ten out of his fourteen children grew up, funds must have been rather meagre; in order to increase his income, he used to take a room in London, and with his eldest daughter spend several days a week working on a translation of the Bible into Spanish, and so I like to think that he was a part author of the *Bible in Spain* by George Borrow. Memories of childhood are mostly rather vague, but certain impressions retain their vividness, and it is hard to say why apparently small incidents remain. I recall going down to Herne Bay, where the old people lived; it was a sunny day in midsummer, and, after passing Whitstable, the distant sea drew nearer; and soon the windless day disclosed a ship with its limp square-sails lazily flapping, as she rolled in a slight easterly swell; and then I heard, for the first time, the gentle murmur of little waves lapping the shingly shore. I often wonder why surf has lost its early meaning, when its pronunciation and spelling were 'suff', which would describe the soft sounds of wavelets, just as 'sough' suggests the rushing sounds of winds in the trees. Only the other day, on such another afternoon, I sat on the shore listening to this unforgettable music, and as the flood tide was making, I noticed that all the little waves approached the sloping shingle obliquely. The highest surge of each wave broke with a sush-sh and the retreating water swished back to be met by the far end of the same wave rolling over with the gentlest sough; and so with tireless melody the waves play their harmonies on our hearts.

The most striking character in old-world bathing resorts was the bathing woman with dark, damp, serge battle dress and black poke bonnet who presided over the proprieties, and dipped the timid little people, and initiated them into the mysteries of immersion. But scents always are linked with memory and the stuffy sticky dampness of the wheeled bathing machine with its indescribably redolent coconut matting, was finally dispersed as with all decency the seaward door was opened, and the authentic smell of sea and seaweed met the bather. It was here that I first saw the ravages of stinging

fish; the man who ordered the movements of the bathing caravans had no thumb and, as children, we were the first to notice the misshapen hand, and with inconsiderate curiosity asked questions. We were told he had had a poisoned hand from a sting. Our curiosity was thus satisfied, but from what I know now, I have little doubt that the sting was from a weever, the commonest stinging animal of the sea-shore.

Seaweed with bladders, shells, shrimps, and fossils were a never-failing interest, but on the edge of the sands (which

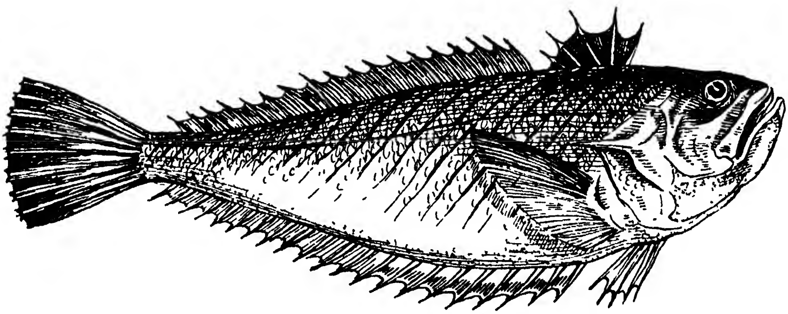


Fig. 2. The Lesser Weever (*Trachinus vipera*)
(natural size)

seemed to extend for miles) covered by a shallow sea, was the Herne Bay Hoy; not the Margate Hoy which has a world-wide interest since Charles Lamb wrote his famous essay. But the Margate hoy was the generic term for a class of Thames estuary coaster, that carried on long after the railways had commenced to knock them out of business. There is very little left on record about these vessels; but they were sturdy craft with bluff bows and considerable carrying powers and were not much use in head winds, so that passengers often spent many uncomfortable hours, rolling at anchor, in very limited quarters. Their rig was very like a modern bawley but the fore-and-aft mainsail was provided with a boom. They also carried a square-sail and square top-sail on yards carried permanently aloft. These details are taken from a model in the

possession of Mr. Frank Mason, who illustrated a book on vanishing craft about 1934; but no mention of Herne Bay in the 'seventies would be complete without some reference to this picturesque feature of the seascape. The smugglers' caves in the chalk cliffs to the east of the town were peopled by us children with romantic ruffians and casks of rum; and it was on these cliffs that the Kent Artillery Volunteers, during their training, fired their guns across the Kentish Flats.

But I have one unpleasant recollection, and that was the stunted land behind the town, where we were taken for walks on Sundays, and above all I loathed the fields with their blackened bean stalks.

The main occupation of the local fishermen was shrimping, and the visitors' children were able to buy small shrimping nets so as to be in the fashion. In more recent times sea anglers go out in boats and fish for topes and whiting.

A shrimper is always liable to get a lesser weever in his haul and in the dark may get 'copped', but the sea-angler is warned by a notice to be seen on the piers, 'WARE WEEVERS'. Passing Sheppey and crossing the London river near the Nore we come to the fishing grounds of the bawley boats from Leigh, which are mostly shrimpers though they also go after whitebait. These boats I knew well, as the two hands on my father's twenty-five tonner hailed from Leigh-on-mud. From the Nore the fingered sands of the Thames Estuary spread out towards the North Sea and on the Maplins may be seen the cockle-galleys or 'cocklers' bumping on the sands, and so to Harwich where there is still a large fleet of shrimpers with their unwelcome guests, the lesser weevers, in their nets. Passing Orfordness the waters get deeper but still all along the coast are longshoremen in their small open boats, fishing within the sands, which extend, with occasional gaps, from Kessingland to Great Yarmouth, called in old charts the Holms of Yarmouth and Lowestoft.

Other areas besides the Thames Estuary such as the sands of Morecambe Bay are equally the home of the lesser weever.

THE WEEVERS

The note of Sir Thomas Browne already quoted does not give a very clear picture of the adder-weever. It is not an ugly fish, and has a rather deep body anteriorly, tapering somewhat towards the tail; the teeth are small and the mouth with a marked obliquity upwards; and the eyes though lateral also point upwards; the coloration is yellow with oblique brown stripes, with a bluish tinge on the gill-covers. But the most striking feature is the anterior black dorsal fin with its sharp spines which, as will be described, carry a venom. This fin is very close to the head. The gill covers are also armed with a spine, which is grooved, projects backward, and is very sharp; this also is the seat of a poison gland. The blackness of the dorsal fin is very marked and it is the only part of the fish to be seen when it buries itself in the sand; so that some writers consider it an example of a warning coloration and it is mimicked by the sole which also buries itself, but erects a black pectoral fin.

We have used the term 'gland' and to avoid confusion it will be well to point out that here the word has no reference to such lumps as children get in their necks when their tonsils are inflamed, or in their armpits when they have a sore on their hand. Gland here means a collection of cells derived from the superficial layers of the skin, modified so as to secrete a poison and often found lining a groove in a fin-spine or dagger-shaped dart projecting from the hinder margin of the gill-cover or operculum.

Chapter 2

WEEVERS AND OTHER STING-FISH

In the last chapter I mentioned incidentally 'bawley boats', a peculiar type of vessel which has been developed in the Thames estuary. Their chief home is Leigh, but they are also found at Grays, Gravesend, and Erith, and all these places I know only too well from my later school days when during Easter holidays we kept our father company, cruising about the lower Thames to the Nore, and up the Medway to Rochester. At one time Harwich had a fleet of bawleys. A typical bawley would be about 35 feet overall, with 12-foot beam, and draw about five feet. They have a straight stem and transom stern, and a rather low freeboard aft, for convenience in working the trawl. The mainmast is short, but carries in summer a very high topmast; the mainsail has a very high peak and has no boom, the main sheet travelling on a horse. These boats are fast, very seaworthy, and suitable for shrimping in the swift tidal waters and the maze of sands between which they have to work. Besides trawling for shrimps, they may trawl for 'five-fingers'; this is the name given by fishers of the 'Lunnon' river to the starfish, which does such damage to the oyster beds. The starfish is not strictly a stinging fish, but there is every reason to believe that it can poison its prey. It has an uncanny way of attacking an oyster, which it sits upon and embraces with its tube-feet. These grasp the bi-valve and steadily pull till the closing muscle of the oyster is tired out, then the starfish protrudes its stomach between the shells, and poisons and then digests the oyster, leaving an empty shell. The bawleys, and also smacks

from Brightlingsea, fish for these pests, as they can be used for manure; and at the same time serve to protect the oyster beds. We have mentioned the Whitstable boats and must here give the devil his due and say that these handsome cutter-rigged vessels are probably as stout ships for knocking about in an estuary as have ever been designed. Their port is one of those harbours that dry out, so that if a north or north-easter begins to blow, their ground tackle has to be very powerful and their timbers so strong that they can withstand the bumping on hard sand without taking any harm. These vessels are solely used in connection with the oyster beds of Whitstable, and several of their features are designed to enable them to work their drag or drudge, which is an instrument dating probably from Roman times.

Before leaving the Estuary, this Eden of edible molluscs, we must just mention the mussels which have given their name to several place- or sand-names. Projecting from the Isle of Sheppey is a spit of sand called Muscle Bank, and there is a group of houses between Leysdown and Shellness called Mousehole, pronounced Mussel. As we go northwards to reach the Swin we pass the Mouse lightship, and it is probable that this name is connected with mussels, because the etymologists tell us that mussel is from A.-S. Muscle (late L. *Muscula*, for *Musculus*) a little mouse, and Mouse in early charts was spelt *Muis*. Our spring cruises never extended beyond Harwich and Dover, and these were often our destination, as we flew the flags of the Royal Harwich and the Royal Cinque Ports Y.C. At Harwich we found ourselves once more among the shrimpers, bawleys and small open boats with a lug, and here we began to meet other fish with a reputation for stinging, besides the lesser weever. Among them is the Father-lasher or Sting-fish which is common in rock pools and shallow water, and is often taken in shrimp trawls in estuaries, as its favourite food is shrimps and small crustacea. This fish, also known as the Short-spined Cottus (*C. scorpius*) is a near relative of the fresh-water Bull-head; it has a very wide distribu-

tion, extending to Greenland, where it may grow to five or more feet, but in our waters does not exceed 0.25 metre. It is greatly feared by fishermen and some consider it as dangerous as the weever. Its markings are striking and the soft hinder portion of the dorsal fin has two sharply marked dark stripes, running obliquely from above downwards and backwards, bordered by white limiting lines, with the rest of the fin yellow. This is a typical obliterative marking and suggests the closed wings of a resting butterfly. The back is brownish and

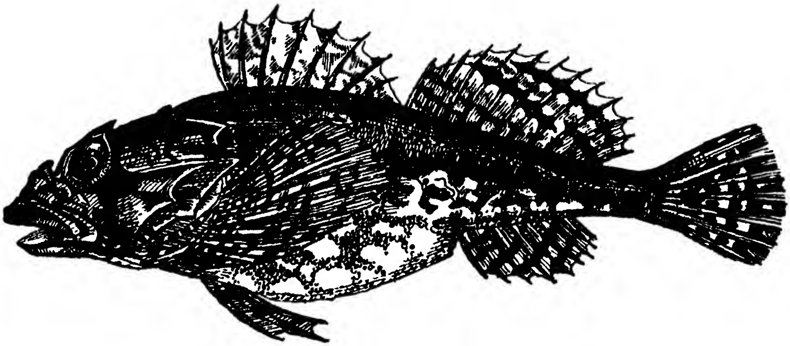


Fig. 3. Short-spined Cottus (*Cottus scorpius*)

fades into a pale yellow towards the belly and the yellow is dappled with oval and round paler spots which would make the body merge with its surroundings. The rays of the pectoral fins are white, interrupted with black spots, while the tail fin is black with rows of small white spots. The head, which is armed like a gurnard's, has several projecting spines on its gill-cover, and these have a cul-de-sac at the base in which is lodged the tissue responsible for a poisonous secretion. The period of spawning increases the activity of this poison gland. This elaborate pattern of stripes and spots suggests that the habitat of this fish would be rocky, where fronds of seaweed would help to provide a suitable background for an obliterative scheme. We find such an area at the entrance to the Harwich estuary known as Stone Bank which lies to the south of the

Cork Sand. This odd name has a strange sound but its explanation is plain if we look at Grenville Collins' Chart (1686). In old charts this sand is marked as the Cork Ledge, Knot or Spit. The old sailing directions were 'the inner channel leads over the Naze flats, the marks being Burnt House Cliff called also Cork Land, kept open to the eastward, will lead on to 'Cork Spit.' The Cork sand therefore takes its name from the cork trees on Burnt House Cliff. The Harwich fishermen have a splendid area of sheltered water in which to cast their nets. From the Naze at Walton down to St. Osyth and the Brightlingsea river, the Wallet is protected seawards by the Gunfleet; this sand was known as Gun-fleet long before gunpowder was used and owes its name to its being in the neighbourhood of Gunna's Fleet, a small stream south of Clacton, and Wallet also owes its name to 'fleet' and we read of Wallflete oysters, in which word there is the first element from St. Peter's-on-the-Wall at the entrance to the Blackwater River.

One summer holiday my father decided to go further afield and with a fair breeze we rounded Orford Ness without any unpleasant tide-rips which may often get up a tidy sea (using tidy in the Suffolk sense) meaning broken irregular water. After passing Aldeburgh Napes the wind fell away and to while away the time we tried 'whiffing' for mackerel, which is more often tried in the west of England than on the East Coast. On this occasion we were successful as the fish had come inshore as they do in July and August. An unusual accident befell one of my brothers as he was unhooking a fish. He got pricked by a small spine near the vent of the mackerel which caused some pain and the wound festered. It is curious how few people have paid any attention to this spine and, in the textbooks, the only notice that I have been able to find is that in Couch who says 'between the anal fin and the vent is a small separate spine'. Nevertheless the fishermen, to whom I have mentioned the occurrence of the evil effects of a prick, agree that the poisonous nature of the spine is common knowledge. I do not suppose that I should have thought much more

of this accident to my brother, if I had not years later had an opportunity of observing the havoc made by another Scombroid (Mackerel family) when visiting Madeira. In the fish market at Funchal I noticed many fishermen with their hands mutilated by a fish nearly related to our mackerel which has a double-grooved poisonous dagger situated between the anal fin and the vent. The spine of our fish is therefore probably a degenerate form of the same dagger and at times appears to be formidable. This I know to be the case, as I had recently to report as Medical Referee under the Workmen's Compensation Act, on the case of a fisherman who had had his little finger amputated as the result of an infection from the sting of a mackerel. This personal experience of three separate incidents thus enables me to write with assurance on an accident the nature of which seems hitherto to have aroused little notice.

Having passed Aldborough we soon saw the chimney stacks of Leiston. I remember well on another occasion experiencing a thunderstorm when in this neighbourhood with the usual shift of wind and my skipper, the old Lowestoft lifeboat coxswain, John Swan, drew my attention to the imminent change of wind by pointing out the way the smoke from these chimneys had veered. There is not much that a longshore fisherman does not notice. A featureless coastline now extends to Sole Bay where a cliff arises from Minsmere haven which shortly is crowned by the last of the ruined churches of the decayed port of Dunwich. Just beyond Dunwich lies Southwold harbour, made by the river Blyth which enters the sea between the two piers at Walberswick, with its fine church tower. Here is a favourite resort of artists and here is a small fleet of small craft engaged in shrimping, going after spring herring and in the autumn having a harvest of sprats. Little soles, flounders, plaice, and whiting enable them to eke a frugal living. Passing Southwold with its lighthouse we sailed on past Covehythe and soon a series of buoys warns the mariner that he is reaching the barrier of sands that extend with interruptions from Kessingland to Yarmouth. At this

time a buoyed passage, the Pakefield Gat, allowed yachts of moderate draught to sail across the sands, and enter the port of Lowestoft without going a long way round through the Stanford Channel.

Thus ended an apparently uneventful cruise, but the results were far different from what anyone had dreamt. Circumstances decreed that *Victoire* was to become a holiday house on Oulton Broad and thus for me began a lifelong connection with the town and harbour of Lowestoft.

Chapter 3

WEEVERS AND OTHER STING-FISH

(*concluded*)

I have just described how we first discovered Lowestoft and said that it marked an epoch in my life. We, the four sons, were now starting on our several careers and so were seldom able to accompany our father on his jaunts. It was therefore decided to tow *Victoire I* on to Oulton Broad, where she remained for several years. In addition, it was thought wise to bring down a fast 18-ft. balance-lug centre-board from Teddington to enable us to explore the broads and rivers of Norfolk, using the old yawl as a mother-ship.

In the fullness of time I became a fully qualified surgeon, and after holding resident hospital appointments I served as a ship's surgeon on Castle liners, travelling three times to Madagascar and Mauritius. It was on these voyages that I first became interested in the bizarre fish of tropical waters and within the reefs of Mauritius first saw the poison fish Synanceia and heard of local remedies for the severe results of its sting. On my last voyage I met by chance a cousin who asked me to take up a government post as surgeon on railway construction on the Vaal Extension through the Orange Free State. This I held till the work was done, and then, as duty called me, I returned to England. After about a year's post-graduate course, including courses in Berlin, I finally joined a surgeon with an increasing practice in Lowestoft. This was in 1894 and there I have spent all my professional life, except from 1915 to 1917 inclusive, when I was surgical specialist to Clearing Stations in France.

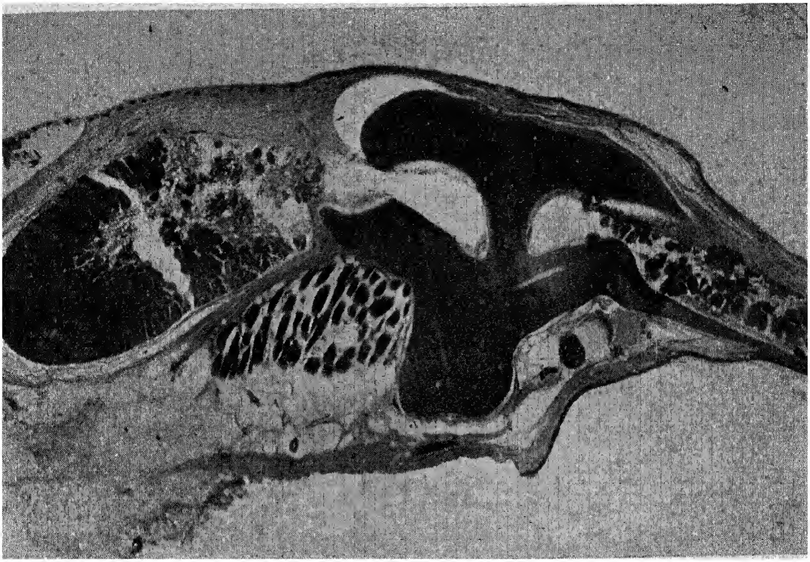


PLATE I

A section across the spine of the gill-cover of the Greater Weever. The two grooves of the dagger-like spine are continued into lateral sacs, that to the left being much the larger, which lodge the poison glands. The larger sac shows the gland in an active state. A muscle, attached to the spine, is also seen.

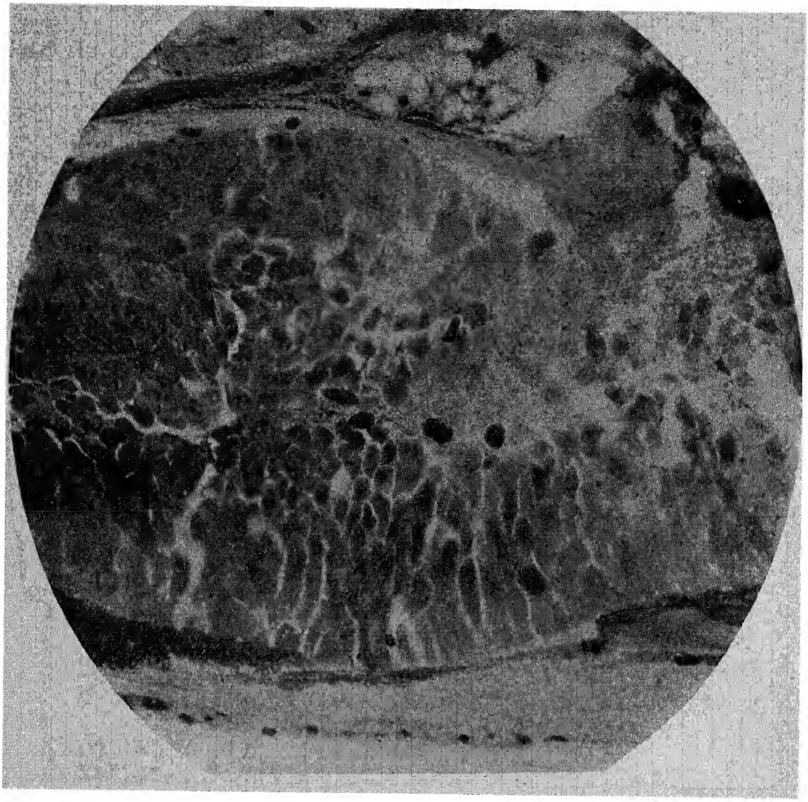


PLATE II

A section of the base of the spine of the gill-cover of the Greater Weever showing the pocket containing the gland in an active state. Large columnar cells contain highly refractile material, which is discharged as round shells, which then burst and produce a granular secretion. Oil Immersion. ($\frac{1}{12}$ obj.)

On starting practice I was at once interested in the seafaring life of my patients and I learnt a lot of fisher-folk-lore and the life history of the fish, which were the livelihood both of drift fishermen and trawlers. But I soon found out that the accidents to which fishermen were exposed, and the diseases to which they were subject, made an unexplored field, and when I had the misfortune to lose a young fisherman as the result of blood-poisoning, after being stung by a weever, I commenced a series of studies on stinging fish which have been the interest of a lifetime and I hope may have been of permanent value to the health and safety of those splendid men, who are now forming the lifeline of England.

I will now introduce the reader to the Greater Weever whose smaller brother we have already mentioned in connection with the shrimpers.

The Greater Weever (*Trachinus draco*)

The greater weever prefers deeper waters and though not a deep sea fish has been taken at thirty-five fathoms, as well as near the bottom on sandy ground. It is found in the North Sea, in the Mediterranean, and along the coast of Africa as far as the Cape of Good Hope. According to Couch it is most abundant on the West Coast of England and Ireland. This fish is from ten inches to a foot in length, though I have seen larger specimens landed from the trawlers at Lowestoft, where large catches are not infrequent. It is a long fish and in form is like a trout but the head is short and compressed, with an oblique mouth, and projecting lower jaw, with numerous teeth in both jaws. The gill-covers project backwards markedly, and are prolonged by a long and strong spine, which carries a poison apparatus. The fins on the back are two in number and lie in a groove; the anterior is short with projecting spines capable of causing painful wounds and, like that of the lesser variety, is deeply pigmented: the posterior is narrower and extends nearly to the tail. The coloration is very striking, yellowish brown on the back, and light

purple on the head, but the gill-covers yellow with light blue stripes. The body is striped with alternate lines of brown and yellow, running obliquely from before backwards and downwards and fading away on the ventral surface. It will be seen from this description that the dark back and light-coloured belly combine to produce what is known as obliterative shading, which helps to make the fish less conspicuous, while the stripes are a concealing decoration which helps to break its outlines and make its coloration conform to its background, in the same way as is observed in many snakes, and other fish, as we have seen with the Father-lasher. The two weevers appear to use their poisoned weapons in different ways. The lesser seems to employ its dorsal fin-spines in a purely defensive way as the accidents that occur are mostly on the feet of paddlers and bathers, who inadvertently tread on them, or on the hands of fishermen who carelessly handle them; but the Greater Weever seems to attack any object approaching it with the precision of a fighting cock, and swings round its armed gills with force and accuracy, if even its tail is touched; this I have myself experienced and thus can confirm similar accounts given by trustworthy observers. Forty years as a surgeon to the Lowestoft Hospital has given me exceptional opportunities to study these fish from the point of view of naturalist and doctor.

Before describing the evil effects of the weever's sting it may be well to consider the exact meaning of sting in the biological sense. A sting is literally a stab but it implies often the existence of a venom, so that the insertion of a sting becomes also the inoculation of a poison.

The name of an object in the world of natural history often enshrines its folk-lore and in this way etymology may become the hand-maid of biology. Thus the word 'weever' spelt by old writers 'wiver' or 'wiuer', will be found to suggest the nature of the animal. 'Wiver' is the same as 'wivern', the N is excrescent as in bittern which Sir Thomas Browne speaks of as 'bitor'. It means a dragon or snake in heraldry. The Anglo-

French *wivre*, Old North French form of French *guivre*, snake, is connected with the Latin *vipera*, viper, influenced by the Old High German *wipera*. The result of this etymological dissertation is to suggest that 'weever' signifies a snake or viper. It explodes the common view that the French *vive* explains the word and that it was applied to the fish because of its tenacity of life. It is now apparent how the official names of the two species *Trachinus draco* and *vipera* are so apt and descriptive.

A few examples of the results of a sting may now be given and I will mention them according to the immediate symptoms

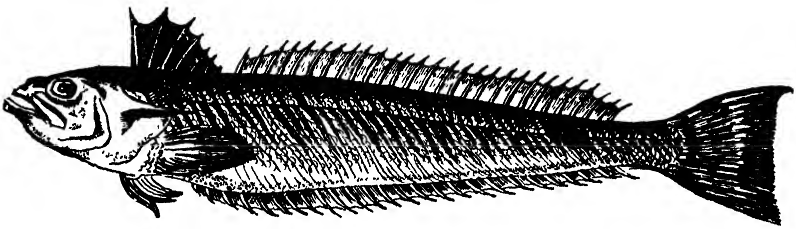


Fig. 4. Greater Weever (*Trachinus draco*)
(one-quarter natural size)

and the after-effects. A little boy was brought to me just after he had trodden on a lesser weever when paddling. He was suffering acute pain, was pale, and his pulse was feeble. There was a punctured wound on the foot and it was tender and discoloured: Lauder Brunton's treatment for snake bite was at once used: the effect was immediate, and the pain vanished, so that after some short rest, he was about again and wanted to return to his companions. A young fisherman was brought up to the Hospital with the tale of a recent sting from a weever while clearing nets in the Market. He had been stung on the hand and the arm was already swollen and tender. But his complaint was of agonizing and excruciating pain. He was given first aid at the Hospital but the house surgeon was not acquainted with the permanganate treatment and he was sent home. A short time afterwards he was brought back to

the Hospital by the police who had found him in a raving state at the railway station. Treatment for the relief of pain was given and local applications applied, but it was some time before the inflammation subsided and he was in a fit state to return home. The intense and agonizing pain is the most characteristic symptom, followed by acute inflammation.

Many tales are told of the extreme measures that are taken by fishermen to relieve the acuteness of the pain, such as hammering the injured part with a thole pin; wrapping a bit of paper in vinegar around the wound and setting it alight; and even attempts are made to jump overboard and requests to have the part amputated. Among later symptoms may be mentioned those that are due to the effect of the poison on the blood. I was called to see a visitor's child by another doctor who was deeply concerned by the large extravasations of blood up the arm of a boy, who two days previously had been stung on the hand. This, I was able to assure the parents, was simply due to the solvent action of the venom and did not mean general blood poisoning, as there were no constitutional symptoms.

In the late 'nineties a sailing trawler was fishing in the north part of the Lemon and Ower sands which lie to the north-east of Cromer when their net had to be cleared of a mass of moorlog which was spoiling their fishing. In the dark the skipper was accidentally badly stung on the hand by the Greater Weever: at first nothing beyond the acute pain was apparent; but in the course of the next day the inflammation spread up the arm which became red and greatly swollen. As the swelling increased they set course for Lowestoft, but foul winds made it a long beat for home. By the time the vessel got to port the skipper was so ill that he had to be taken home in an ambulance. I was called in to see him and was at first rather puzzled with the case, as I had never heard of weever poisoning and moreover the usual textbooks made no mention of it. The local symptoms had meantime greatly increased, and there were signs of general blood-poisoning. In spite of careful

nursing and constant attendance on my part the unfortunate man died. This episode naturally produced a profound impression on me and I determined to investigate the nature and pathology of this new disease, and to find if possible a specific treatment for it. I will not forestall my findings but if the reader refers to the first case that I described above he will notice that by that time a real and valuable advance in the treatment of wounds from venomous fish had been devised with remarkable results.

The poison organ of the Weever (*Trachinus draco*)

The poison organ of the Weever consists of glandular tissue which is developed in connection with the dorsal fin-spines and the spine which protrudes from the hinder margin of the gill-cover or operculum. The structure of the gland and the way in which the poisonous secretion is discharged are very similar in both sites, so that it will only be necessary to describe the more important, namely the opercular gland. The opercular spine is dagger-shaped and both the upper and lower margins are grooved from base to tip, except at the protruding naked point; it is ensheathed by an extension of the external skin and in each groove lies a pear-shaped mass of glandular cells, the broad base of which is received into a conical cavity and thence extends more widely between the epidermal coverings, finally tapering towards the tip. The gland is a 'tucking in' or invagination of the external skin, the cells of which have become modified and much enlarged. A section of the gland near the base shows a mass of cells arranged in columns, resting on a basement membrane and pointing towards the centre of the gland. When in an active state the gland cells, columnar in shape, are seen to be filled with a highly refracting substance, which in sections stained with van Gieson's stain appear bright yellow. The bursting of the cell discharges this refractile substance as a spherical body or globule which stains deeply with haemalum; this again is seen to burst, and this disruption produces fine granules, staining blue, which

are the final stage of the secretion. In these war-like times the simile of shrapnel seems apt, the shell being discharged from the cell and then bursting in the lumen of the gland. The entrance to the gland at the tip will admit a small-sized knitting needle, so that the best way of obtaining the secretion is to pass an exploring needle of this calibre down to the base

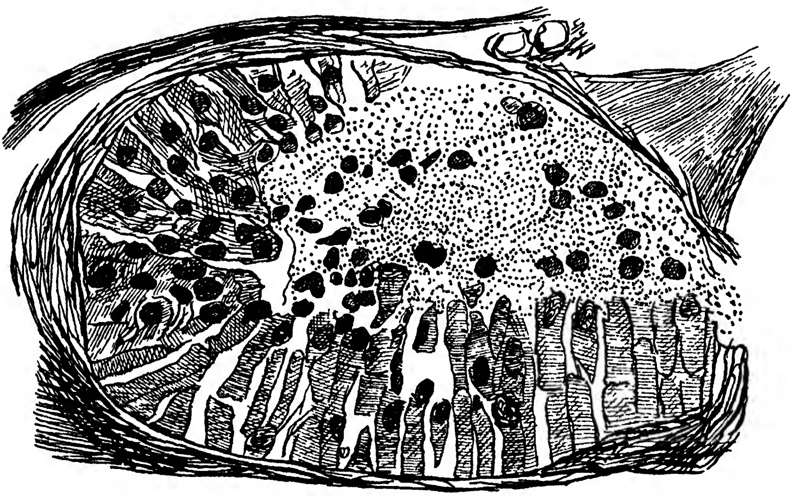


Fig. 5. Transverse section of the gland of the opercular spine of the Greater Weever across its base to show the large columnar cells discharging globules which then burst and form a granular secretion.

of the gland, and to suck out the contents with a syringe. In this way a fairly pure specimen can be obtained, although it necessarily contains some cellular elements.

The acute pain and subsequent inflammation are the most striking after-effects of a weever sting. In the study of venoms one of the most important symptoms is the dissolution of the red corpuscles producing a condition known as haemolysis. The same phenomenon is also seen in the study of weever poisoning. Leaving this phenomenon for the present, we will look at another aspect of the blood condition resulting from

inoculation of weever venom. Many people attribute most of the effects of the weever's sting to what is called secondary infection, but they give no explanation why this sting should almost invariably be accompanied by what might be called after-effects. In an attempt to solve this problem I have made some simple experiments and have followed a technique modified from that of Sir Almroth Wright, which he has used in studying man's defence against tubercle. He investigated the power of the white cells to attack and destroy the tubercle bacilli and made blood films to show the number of bacilli in the body of the white blood corpuscles (leucocytes) which varied according to the power of resistance of the patient. This he called the 'opsonic index', or the appetite of these cells to ingest and digest the tubercle bacilli.

In my experiments I applied this principle to the power of the white cells to attack ordinary infective micrococci in the blood of a healthy person, and compared it to the power to attack these organisms when this blood was contaminated with weever venom.

To describe one experiment will suffice to illustrate my method. Two capillary tubes were each filled with blood from my pricked finger and a little emulsion of staphylococcus pyogenes (the common germ of suppuration); in one tube a little salt solution was added, and to the other an equal quantity of salt solution to which a trace of weever venom had been added. Both tubes were sealed and put into an incubator at the body temperature. After a short time the tubes were removed and films were made of the blood, stained, and examined microscopically. In the tube with *saline only* large numbers of cocci had been ingested by the white cells, whereas in the tube with *saline to which the venom had been added*, very few cocci were to be seen in the body of the cells, and the cells had taken the stain badly and their nuclei were indistinct. Such an experiment is conclusive proof of the power of the venom to break down the resistance of the blood to ordinary infection and seems to be most instructive. It shows how the

ront line troops, the leucocytes, had been overwhelmed, and as here had been no time for reserves to be called up, the germs ad an uninterrupted entrance into the system. This paralysis f the leucocytes together with the dissolution of the red cells, eems to be the correct interpretation of the frequent inci-lence of secondary inflammations in the course of envenima-ion from poisonous fish.

Chapter 4

THE SPURDOG OR SPINY DOGFISH

In the late summer and autumn the herring shoals collect in vast numbers in the more southern parts of the North Sea, and a fleet of drifters collect at the fishing ports for the herring harvest. The old days of the picturesque Scotch luggers, the Zulus and the Fifies, are past with their huge, rich red, curtain-like sails, and their place is taken by the more efficient but much more expensive steam drifters, with their miles of drift nets and their smoke-stained mizens. Any morning at this time of the year the harbour will be crowded with vessels coming in, like a procession, and nosing their way in to find a place to tie up, among the crush of boats, already unloading their catch on the market quay. The buyers are also there in force and the air is one of brisk expectancy, as the in-coming boats are seen laden down to the gunwale with their morning's catch. At times the boats are seen returning too soon, not on account of the weather, as it has been a clear moonlit night, but because that scourge of the herring shoals has scoured the seas and the predatory packs of dogfish have ravaged their defenceless prey, and rent the nets, causing not only the loss of a night's catch but also hundreds of pounds' worth of damage to gear. The Spurdog or Spiny Dogfish is spoken of as a gregarious shark, being one of the smaller class of sharks; and its habits are to roam the seas sending out scouts to find the herring and pilchard shoals. It is difficult to find the right word to convey the terror of the vast numbers of marauding fish and their mode of attack. Such words as shoals and herds seem too peaceful and one falls back on words like 'pack' which suggest wolves and vicious attack; and this may be the reason for the

name 'dog' being applied to this fish with its wolf-like associations. The scale of these holocausts of herrings is vast; it is on record that off Cornwall, where they appear in the greatest numbers, they occupy 'the full extent of the sea for scores of miles; and twenty thousand have been taken in a seine at one time without any apparent lessening of their numbers'. The damage that is done is not only by their sharp cutting teeth but by the spines which arm the front aspect of each dorsal fin. Each spine is stout and sharp and has a groove facing backwards, the anterior spine being the longer; these have a tearing power, and in the use of them there seems to be the possession of intuitive knowledge.

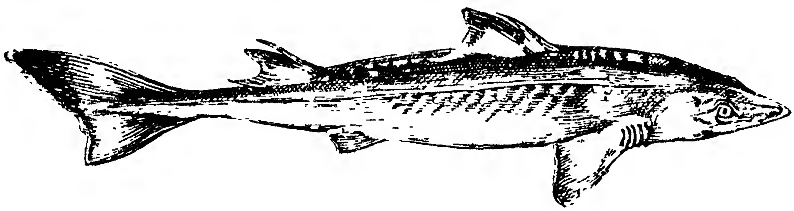


Fig. 6. Spiny Dogfish (*Squalus acanthias*)
(one-tenth natural size)

Couch has described how the spurdog uses its spurs or pikes; another name for this fish being Piked or Picked Dog (*Squalus acanthias*). 'If laid hold of by the head they will bend the back into a bow, and so bring the spines into a favourable position for a backward stroke, which is effected by a sudden and violent return of the body to the straight posture. The spines are thus thrust asunder in such a manner as to tear anything that lies within reach of the stroke; and as a defence this action is so efficient as to demand from the fisherman some care in the handling of it; for the fish is able to direct its spines with a considerable degree of precision'. It was as the result of such an action that my notice was first drawn to the danger that was present in a wound from a Spurdog. Towards the end of October 1919 a fisherman came up to the Lowestoft Hospital with a poisoned hand. There was a punctured wound at the base of

the thumb. Six hours previously he had been pricked by a dogfish. This caused acute stabbing pain in the part lasting four or five hours, when the hand began to swell. When I saw him, there was great swelling and puffiness at the back of the hand, and the front of the wrist and forearm were painful, red, and showed signs of inflammation. Owing to the lapse of time since the injury no special treatment was applied to the wound. If I had seen the case earlier a weak solution of Condy's fluid (5% solution of permanganate of potassium) would have been injected into the site of the puncture, as I have found this procedure immediately relieves the pain and other symptoms which follow the sting from the poisoned spines of the Lesser and Greater Weever. As this was the first case of injury by a dogfish that had occurred in my experience, I was anxious to investigate the nature of the poison, if any existed, and for this purpose I obtained a number of fresh spines. The material was easy to obtain as not only were large numbers of dogfish being landed but the back-fins and dorsal spine can be cut off in one piece with a sharp knife without in any way affecting the commercial value of the fish. To return to the injured fisherman, the inflammation lasted for four days and it was feared that an abscess would form but on the fifth day the swelling had begun to subside; yet it was not until seven days had elapsed that the swelling and tenderness over the wrist had disappeared and that the patient was discharged convalescent.

We must now have a good look into the attachment of the spine and in doing so our attention is at once drawn to a groove on the aspect of the spine, facing the anterior margin of the dorsal fin; this is occupied by a glistening pearly-white substance which towards its base shows a small linear depression in the middle line; this aperture, as that is what it really is, extends for about one-sixteenth of an inch, and leads into a minute cavity surrounded by a number of smaller crypts lined with cells, which apparently pour out a secretion, as the orifice is often discoloured by some substance formed by the gland.

All this can be seen by the naked eye and more details can be observed by examination with a lens, when it will be noted that the gland commences at the junction of the fin and spine and that the fin seems to support the base of the gland. My next procedure was to investigate the nature of this pearly tissue, and I therefore removed some of it with the point of a fine scalpel, and spreading it out on a clean slide shredded the fragments into the finest particles by tearing the tissue between the points of two needles, devised for the purpose. In this way, by what is referred to by learned biologists as 'teasing', I have persuaded the glistening tissue to reveal its secrets. The fragments show that it is made up of a number of small cells, seen clearly under the microscope to be of different shapes, and arranged in a definite pattern, which is typical of the arrangement of the cells in such an organ as a gland in the human skin, which produces the greasy matter known as sebaceous (L. *sebum*, tallow). It must be clearly understood that the microscopic structure of any particular gland throws little light on the nature of its secretion, and the same anatomical structure can produce saliva, tears, and other fluids. What we have discovered, therefore, is only that our glistening white tissue has the anatomical structure of a gland. The next point to notice, and this can only be found out by more complex methods, is the arrangement of the cellular elements so as to produce a definite organ with a median opening. There is no comparable gland to be found in the human skin, but I have had the opportunity years ago of making a number of researches on what are known as 'face glands', found in deer, antelopes, sheep, and goats. My work has led me to examine these glands in several species of South African buck and I have found that they are the result of a depression or inverted fold of the skin which results in a mass of little bags or follicles, each of which is lined with several layers of secreting cells, those towards the centre being often swollen and distended with the substance it is designed to produce. The tissue of the groove of the spine of the dogfish has the same structure,

though it naturally differs in details. It may help the reader to visualize this structure, if each follicle be looked upon as a finger of a microscopic glove with all the fingers opening into a central cavity which opens on the surface where the glove narrows at the wrist. The innermost layers of the cells in the follicles of the spine-gland become distended with globules of a clear substance, and these coalesce and burst into a converging

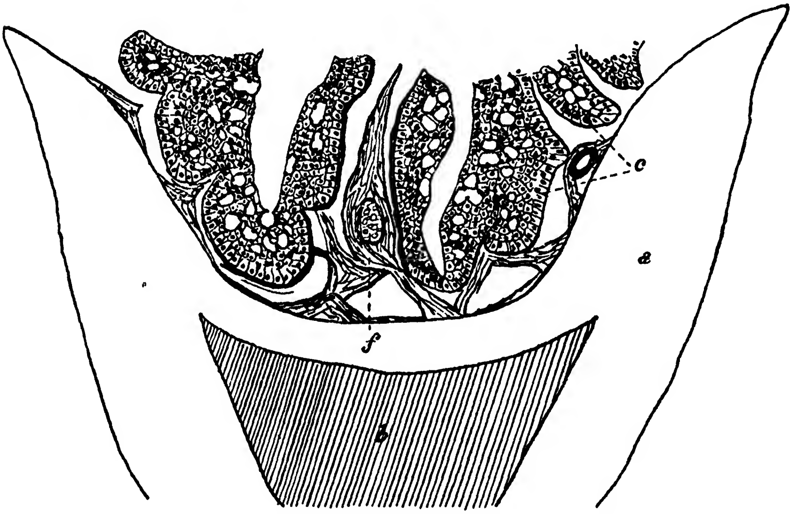


Fig. 7. Transverse section of the dorsal fin-spine of the Spiny Dogfish showing two follicles of the gland, *c*, separated by a median septum. *a*, dentate margin of groove. *b*, central cavity of spine. *f*, base of groove.

duct which joins the central cavity. All the follicles are supported by a fibrous framework arising from the groove of the spine, and it is important to notice that this framework also contains channels associated with the presence of a black pigment, either free or lining blood-vessels: the significance of this pigment will form the basis of a wide biological discussion of great interest and will be mentioned later in this work. These details have been obtained from the study of serial sections from which I have completed a picture of the gland

from base to tip. In this way I was able to observe that the gland arose from epithelium at the base of the fin and to note a special layer of large pigment cells, which, we shall see, bring the crude material to the gland which then elaborates its proper secretion. What is the nature of this secretion? I believe that I was the first to examine the spine and its gland by modern methods, and all this work has been recorded elsewhere in full detail. To confirm the clinical results on man I have made experiments on fish. The injection into a roach, subcutaneously, of filtered glycerine extract of the gland substance of the spine of the dogfish produced the following symptoms: After a period of fifteen minutes to half-an-hour in which the fish lay at the bottom of the dish and the respirations became very frequent the general symptoms subsided. Local swelling and puffiness then arose at the site of injection, the scales became erect and fell out, but no abscess formed. The fish looked ill and became dark and dull-looking like a fish kept some time in a bait can. Recovery was slow and no suppuration occurred. These experiments and the history of other pricks on many fishermen, and their retriever dogs, leave no doubt of the poisonous nature of the gland of the Spurdog.

The Port Jackson Shark

The recognition of the poison gland in the dorsal spine of the Spurdog naturally turned my attention to the search for other sharks with spines connected with their fins that might have poison organs. With this in mind I visited the Museums of the English Universities and the British Museum of Natural History, and returned home very grateful for the help I had been given by the responsible Professors, and furnished, through the kindness of Professor Goodrich of Oxford University, with a specimen of the dorsal fin-spines of *Cestracion Philippi*, the Port Jackson shark. It is no fault of mine that I must inflict on the reader yet another name for this fish; but the systematists have decided that the name 'Heterodontus' must be used instead of Cestracion. But instead of

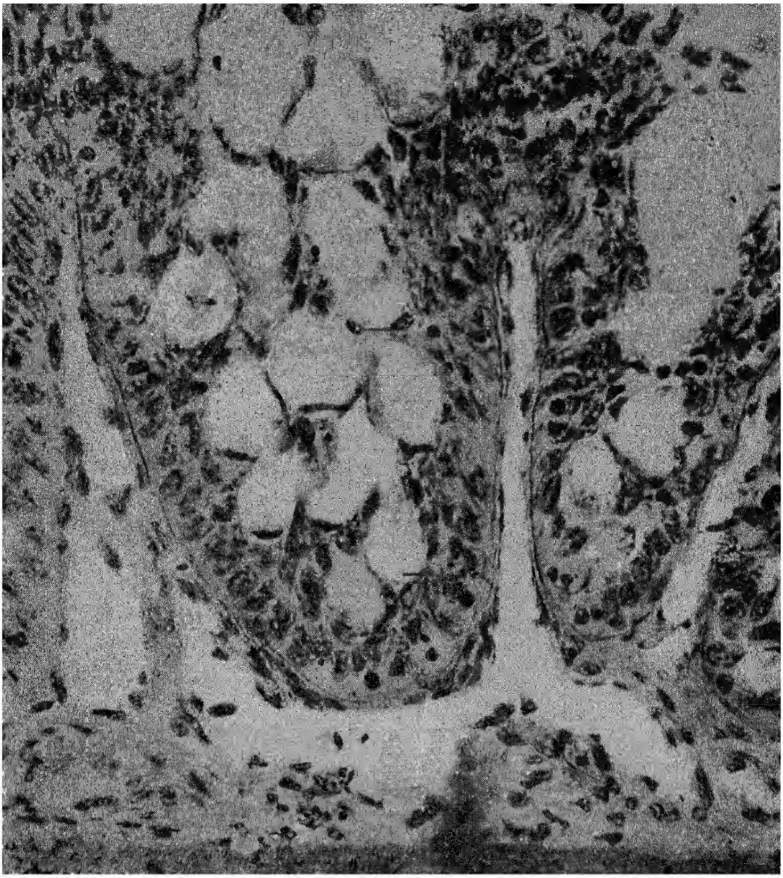


PLATE III

A section of the gland of the dorsal spine of the Spiny Dogfish. Two follicles are shown resting on the spine, that on the left shows a number of distended cells, while on the right these have coalesced so as to form one clear area in the periphery of the follicle (high power).

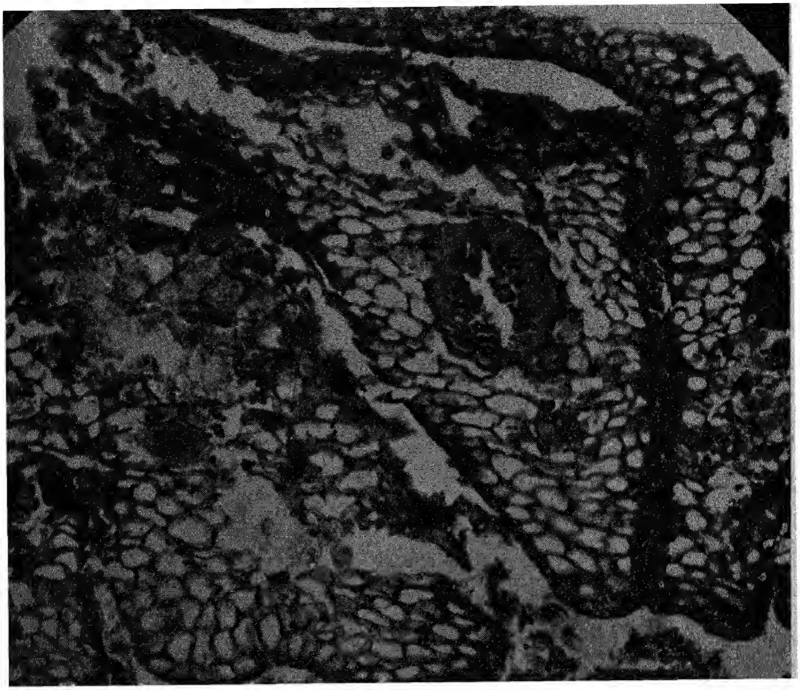
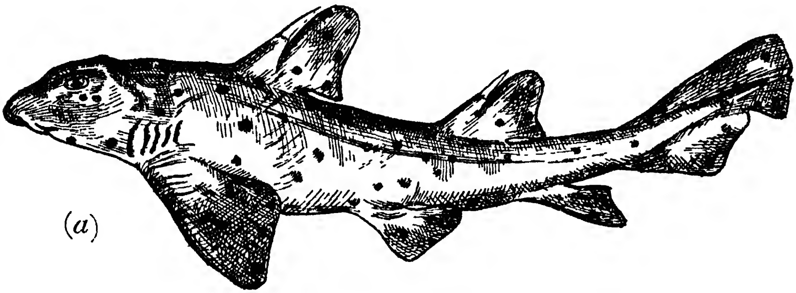


PLATE IV

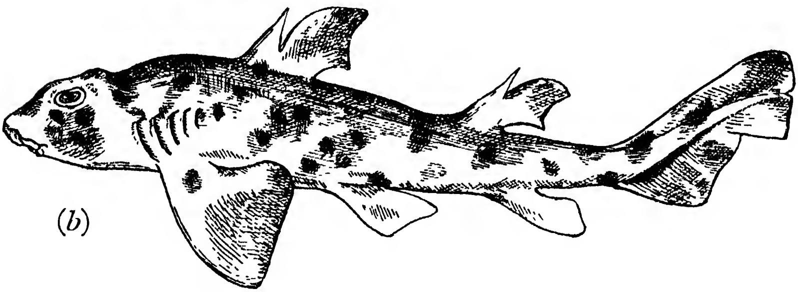
A section of the gland in the groove of the dorsal spine of the Port Jackson Shark. To the right is a follicle in the form of a triangle, in the centre of which is a mass of secretion circular in shape and showing several globules (high power).

using any of these names I propose to talk of the Bullhead shark, the name by which the public probably know it best.

The interesting point about this shark is the existence of dorsal spines similar to the dogfish's. But regarding its distribution, its antiquity, and finally its habitat and diet, in all these points except the second it differs from the Spiny Dogfish, which



(a)



(b)

Fig. 8. (*a*) Port Jackson Shark (*Gyropleurodus Francisci*) a specimen with discrete spots. (After Tosio Kumada)
(*b*) Port Jackson Shark (*Gyropleurodus Fransici*) a specimen with spots becoming stripes. (After Tosio Kumada)

as we have seen extends widely as a pelagic fish in the temperate waters of both north and south hemispheres. The Bullheads on the other hand are found only in the Pacific Ocean and are confined to Australian waters, the coasts of California, and the Galapagos, and also Japan. Professor Beebe has written on the sharks of the North Pacific, but I have learnt much of the habits of Bullheads from an Atlas of Californian fishes lent me

by the Ministry of Fisheries, which has drawings reproduced by a new and interesting technique. Fishes, caught by trawl, were frozen as soon as brought on deck, and sent to the Institute, where they were melted slowly, and sketched at once in a natural state, before they had time to fade. They were then put into formalin and fixed. Then large-sized photographs were taken, and from these prints tracings were taken and outlines and details filled in. Any details of the colours were

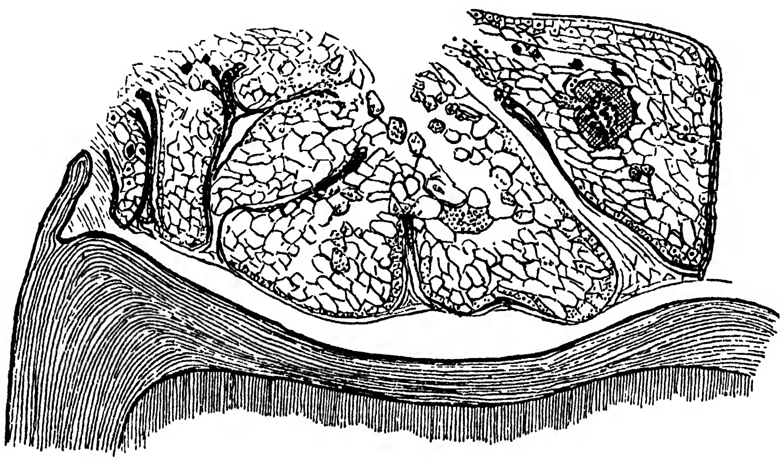


Fig. 9. A transverse section of the gland of the groove of the dorsal fin-spine of the Port Jackson Shark. The follicle to the right shows a mass of secretion in the centre of the follicle. Note the supporting ridge on the margin of the groove.

revised by the artist who had seen them in the fresh state. The result of the application of this method is a series of accurate drawings such as I have never seen before, and one may hope that this method may be more extensively used. In drawings of the Port Jackson shark several broad black bands, three or four in number, run transversely. Drawings of the same species obtained on the Mexican coast show that, in the place of the bands, black spots occur in the same areas and shading is seen around the spots, so as to convince a careful

observer that the change from black bands to discrete black spots has been taking place at the time the photograph was taken. The importance of the initial freezing is to fix the chromatophores and iridocytes which otherwise relax or change after death; and thus the coloration is preserved. The fact that this shark has a habitat near the bottom is confirmed by these obliterative markings, which are not usually seen in pelagic fish, and the fact that its diet is purely crustacean and involves the crushing of hard shells, is confirmed by the powerful jaws, with numbers of obtuse pad-like teeth. If the picture of a judge in his full-bottomed wig is turned upside down, and the face is disregarded, and its place be presumed empty and to be the anterior end of the space occupied by the upper jaws, there is a rough sketch of the arrangement of the teeth represented by the curls of the wig, small round the face and larger towards the lower part. Against these teeth there meets a central pad on the lower jaw. This short account of the Port Jackson shark gives some idea of the difference between it and the Spiny Dogfish, and when it is stated that the former has a similar poison gland to that we have already described, it will seem strange that it is in this respect only that the two sharks are alike. But a still stranger fact is the history of their geological ancestry. Both fishes have ancestors as early as the Devonian period and these ancestors were of enormous size and armed with huge and barbed spines. These have been studied in specimens from the Lias of Lyme Regis where both teeth and skeletons of extinct forms have been found. The best-known of these spines is that of *Hybodus*, very closely related to the Heterodontidae. It is hardly necessary to go into the minute detail of the differences between the poison glands of the Spurdog and the Bullhead shark; both glands can be seen by the naked eye to occupy the groove of the dorsal spines. But the groove of the Bullhead is shallower than that of the Spurdog and there is a median elevation in the centre of the groove of the former and, further, it has a lateral bulwark on its outer edge which gives support to the glandular tissue.

These details of the groove are important as they explain the details of the grooves of the ancestral sharks and enable us in imagination to clothe these fossils with living tissue, which we are also entitled to believe to have been of a venomous nature. An era of monstrous sharks with poisoned spines can thus be visualized.

Chapter 5

THE STING-RAY

Another sting-fish found not infrequently on our coasts is a member of the family of Skates and Rays. A typical Ray has the body flattened from above down, and this together with its expanded pectoral fins makes a more or less circular disc.

In describing the sting-rays I shall confine most of my observations to *Trygon pastinaca*, as this is the only species seen on our coasts. These rays have the pectoral fins prolonged forwards, so as to meet in the middle line in front of the snout. The tail is long and whip-like, but carries no fins as do other rays, but instead it bears a long and strong arrow-like dart which is toothed on either side; the aspect facing the tail is somewhat flattened, and adjacent to the serrated edge is a deep grove which in the fresh state contains a glistening substance, which we shall see, consists of cells modified to form a poison gland. In the course of centuries the study of this gland has been frustrated by incomplete investigation, which is excusable when the hardness of the dentine, which forms its couch, is considered. It was only after repeated attempts and numerous failures that perfect sections were cut which revealed the complete gland with all its details intact. Fishermen throughout the ages have known that the spine of *Trygon* was venomous, but by a strange see-saw of scepticism and conviction scientists have doubted or believed in the presence of a poison organ.

Every year in the autumn sting-rays appear, most frequently on our southern coasts, but I have known of specimens landed at Lowestoft. The fish has no commercial value but the fishermen prize the oil obtained from its liver, which they

firmly believe is a specific for burns, and, in the old days of sailing trawlers, every trawler carried a bottle of this oil as part of its first-aid outfit. To test whether this view was not merely superstitious, I obtained a sting-ray and boiled down its liver and got a rather pungent-smelling oil; I found that it was quite a good application for burns, but my other experiments were not sufficiently convincing to relate here. The fisherman's profound belief in the efficacy of this oil not only for burns, but also for wounds and rheumatism, may be a relic of past superstitions. Among the ancients the spine was considered to have almost miraculous properties. They held the opinion that if 'the spine was burnt and the cinders mixed with vinegar it acted as an antidote; it relieves toothache and helps cases of difficult dentition; if attached to the navel of a woman it causes her to have easy childbirth, provided it be taken from a living ray which is then thrown back into the sea.' Sir Thomas Browne quaintly remarks 'It is conceived of special venom and virtue'.

The opponents of the view that the sting-ray's tail carries a poison organ base their objections on the fact that their observations have been unable to demonstrate any gland. Their attitude is well expressed by Aldrovandus: 'I have searched', he says, 'for a poison organ in *Trygon*, and have not found it, therefore it does not exist.' 'These fish are dangerous only on account of the mechanical wounds that they make, and the depths to which their spines penetrate.' The undoubted effects of the sting, the excruciating pain, numbness, and loss of power are, by even modern sceptics, attributed to the mucus on the skin, and the bad after-effects are held to be due to a bad habit of body, which allows the lacerated wounds to fester. Couch held such views and the eminent zoologist Ray Lankester was just as emphatic and, what was more regrettable, discouraged the efforts of an old student to settle the question. My former teacher tore up my first contribution to the Royal Microscopical Society and did not reply to my covering letter. These personal matters may seem trivial but I mention them

here to indicate that young men need not be intimidated by the exaggerated reputations of their seniors. My own reaction was increased determination to get to the bottom of this question, and so once more I took off my coat and returned to my laboratory. And now I can express my lasting gratitude to this great man, who was later to be superseded as the head of the British Museum of Natural History by Dr. Tate Regan the eminent ichthyologist and Keeper of Fishes. It was owing to my further efforts that a clearer knowledge of the gland of the spine of *Trygon* was gained, and Dr. Regan submitted my paper to the Zoological Society of London, and in due course it was published and has become part of the general knowledge, relating to fish venoms. This would not entitle me to any particular credit, if it had not been a stepping stone to far-reaching researches on the Spiny Dogfish, the Port Jackson Shark and the Chimaeras, and incidentally to their bearing on fossil fin-spines known as 'ichthyodorulites', which formed the basis of a paper published in *The Philosophical Transactions of the Royal Society* (B391.7.2.23). The encouragement and help I received from Sir Henry Hallet Dale, now President of the Royal Society, in preparing this paper which was communicated by him, were a turning point in my life, and the study of problems in the biology of fish has occupied all my leisure since that time.

The serrated spine of the Sting-ray should be looked upon as the first dorsal spine of a dorsal fin that has become obsolete. In other rays two dorsal fins still remain and like the spine have been shifted on to the tail. It is not surprising therefore that it is part of its hunting equipment, rather than a weapon of defence. The spine as a defensive weapon has no value when the Hammer-head shark is feeding. It is recorded that a Hammer-head was harpooned when it was chasing sting-rays across a sandy flat; in its stomach were the partially digested remains of rays but there were no less than fifty spines embedded in various parts of its body, in the neck and back, but mostly in the mouth and gullet. Some had become embedded

in cysts. The Tiger shark is said by Norman to attack large sting-rays and has been seen to circle round its prey, as if sparring for an opening, and then to dart in and seize the ray, in spite of the vigorous lashings of the tail. These examples do not support the defensive theory. On the other hand Beebe describes how yellow tails may be peacefully feeding and suddenly a watcher sees a sting-ray approach and the flock disperse in terror. Deep-sea anglers also describe how if carelessly handled a sting-ray will grasp a limb with its flexible and prehensile tail and drive its sting deeply into the flesh. So that the evidence as far as we can tell from these observations points to the sting being an offensive weapon. Mr Russell J. Coles has given his own experiences of a sting from the Spotted sting-ray (*Aetobatis narinari*). While handling a large specimen of this fish, it 'threw its body against me and drove its poisoned spine into my leg above the knee, for more than two inches, striking the bone, and producing immediately a pain more horrible than I had thought it possible that a man could suffer. The pain was like that produced by coming in contact with the long filaments of the Portuguese Man-of-War. I braced myself against the body of the brute and tore its barbed spine from my flesh. In less than five minutes I had attached a long needle to a hypodermic syringe, inserted the needle into the bottom of the wound and injected a syringe full of an antiseptic fluid called "formalid". This was repeated until all the secretion was cleared from the wound. The result was magical, the pain did not subside, it ceased instantly, and the wound was entirely healed in less than twenty-four hours.'

If we now cross over to the Pacific Ocean we shall find other species of sting-ray equally venomous. In one of Mr. Masefield's novels is a vivid account of the effects of a sting on a sailor; Sard Harker, the hero, has got lost on the Southern Pacific shore. 'He was trying to work his way down the coast, when his progress was stopped by a quicksand, the shore end of which was tropical bog; so he decided to swim round the seaward end. He went knee-deep into the sea with some mis-

givings, for the shallows of all that coast are haunted with sand sharks. He splashed, as he went, to scare them. He had gone about thigh deep into the water and was about to swim, when there çame suddenly an agonizing pain in his left foot; as the pain ran in a long stabbing streamer up his leg, he realized that he had trodden on a sting-ray. He hopped out of the water to the shore, feeling all the blood in his foot turn to vitriol, and come surging to his heart. Most excruciating agony made him fling himself down. He tried to hold out his leg, but that was unendurable torment. He tried to kneel upon it while he put a ligature above the knee, but the pain made him so sick that he could not bear it. He tried to lie down but that was unbearable. He rolled over and over moaning; then staggered up and hopped and hopped gasping with pain until he fell. Although he fell, the pain did not stop; it grew worse. The cold deadly flat thing had emptied his horn into him. He buried his face in the sand, he dug his hands into the sand. Then the poison seemed to double him up. It seemed to burn every vein and shrivel every muscle and make every nerve a message of agony. The foot no longer looked like a foot, but like something that would burst. He said that his foot was dead and would drop from his body and never grow again. He became delirious . . .'

After a long time Sard roused himself up 'feeling weak and sick. He sat up and tried his left leg.' 'He then felt for the first time that he had only one leg, that the other would not act. He could not move it: the thing ceased to be his; it neither obeyed nor rebelled, it failed. He was so cold that he felt he would die. He sat for twenty minutes trying to restore his leg; the pain had gone, but it was as though the poison had burnt out the life. In some ways he would rather have had pain than this deadness, and the numbness was made worse by the swelling. When he dented the flesh by pressing on it the dent remained. All sensation from the mid-thigh to his toe was lost.' We need not continue the narrative, but this graphic description will give the reader a better idea of the symptoms

of a sting-ray wound than any account expressed in the clinical language of a surgeon.

I propose now to give a few more details of this much-disputed gland of *Trygon*. The lateral groove of its spine appears in sections as a triangle which I have called the glandular triangle,

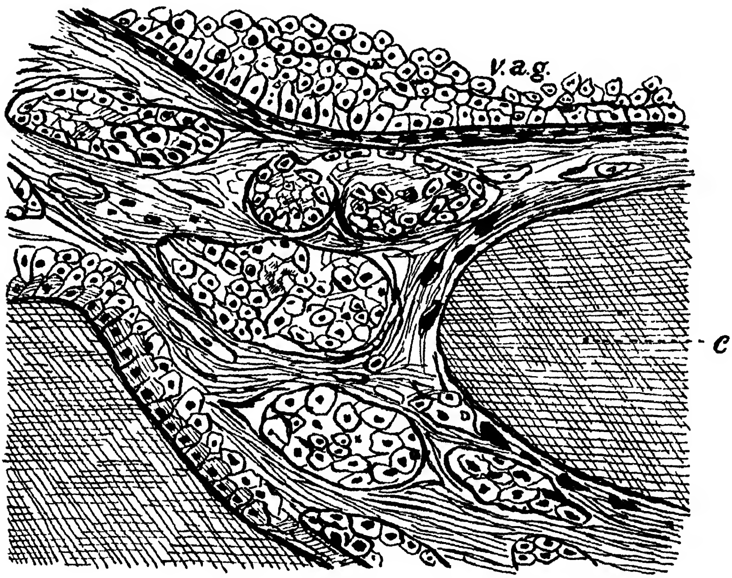


Fig. 10. Section of the caudal spine of Sting-ray to show the tissue in the deepest part of the groove.
c, part of the central canal with pigmented walls and clear contents; also blood-vessels and the layer of pigmented capillaries separating the alveolar portion from the layers of secreting epithelium, v.a.g.

and it consists of two parts. The deepest is small and consists c cavities, probably canals and blood-vessels (see Fig. 10 and 11 the former bring the supplies of material to the more superfici portion which consists of layer upon layer of secreting cel which as in the weevers is modified epithelium. These tv areas are separated by a layer of pigmented blood-vessels, co sisting of capillaries with pigmented walls, and this gives

processes which project into the glandular portion and provide for its nourishment and contain pigment. Towards the tip of the spine these processes are prolonged so as to provide covering flaps on either side to protect the cells which here have no protection from any adjacent structure. When the gland is

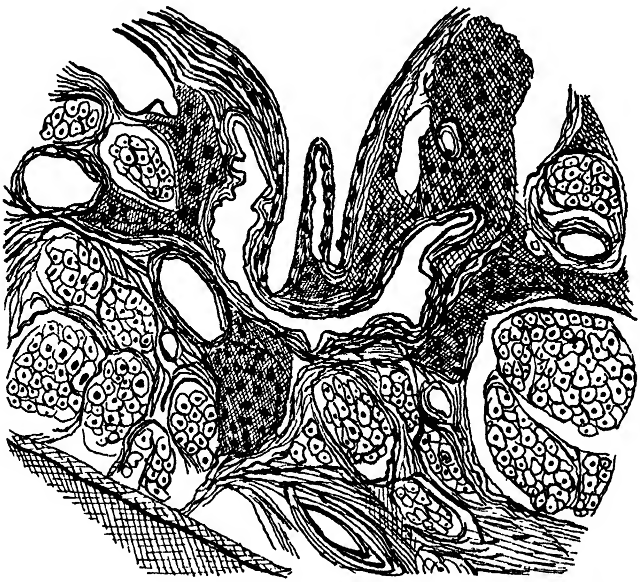


Fig. 11. Another view of the deep alveolar portion of the tissue of the groove. The central canal is collapsed and empty and the pigmented capillary layer is sunk inwards and in the pit is a nipple-like protrusion. Three smaller canals are seen and blood-vessels. The superficial epithelium has fallen away.

active columns of cells appear in which all the stages from a resting state to its transformation into secretion can be observed; in advanced stages the secretion can be seen, being discharged in the direction of the teeth of the spine. In addition to these cellular changes I have noted that the margins of the secreting areas are filled with chains of pigment granules and also a few scattered masses of pigment. There seems no doubt that here we see the waste material, pigment, probably

melanin, brought to the cells for the manufacture of a venom. In more recent years the pigmented blood vessels have been described by Marie Phisalix as a *réseau capillaire pigmentaire* in connection with the poison glands of the skin of the Salamander.

The above description will be more readily understood if the reader looks at the accompanying drawings:

Fig. 10. The deep portion of the glandular triangle with the central canal distended. Some parts of the true gland remain *in situ*.

Fig. 11. The deep portion of the glandular triangle, in which the central canal is collapsed, and the secreting epithelium has come away in decalcification. A nipple-like projection of the pigmented vascular layer lies just above the canal.

Fig. 12. Is a drawing of part of the tail and the serrated spine, and below two sections of the same, across the lines indicated.

Fig. 13. A portion of the spine in transverse section showing one lateral groove with the glandular triangle.

Fig. 14. A similar section of the spine but near its tip showing how the glandular tissue is protected by the lateral flaps.

Fig. 15. A section similar to the preceding from another species of Sting-ray. Here the glandular epithelium is complete and the lateral flaps enclose the tissue which is in an active state and a drop of venom is seen exuded.

Fig. 16. A high-power drawing of the glandular epithelium showing all stages of secreting cells, pigment granules, and secretion.

The venom of the Sting-ray

The recognition of a black pigment in the epithelial gland of *Trygon*, together with the presence of a network of pig-

mented capillaries, opens up a wide biological field for discussion and investigation. The study of the *Mollusca* introduces the Cuttlefish (the cephalopod Sepia) which has the power of both producing a smoke-like screen by squirting out a spray of sepia, and a poisonous secretion which paralyses crabs. The

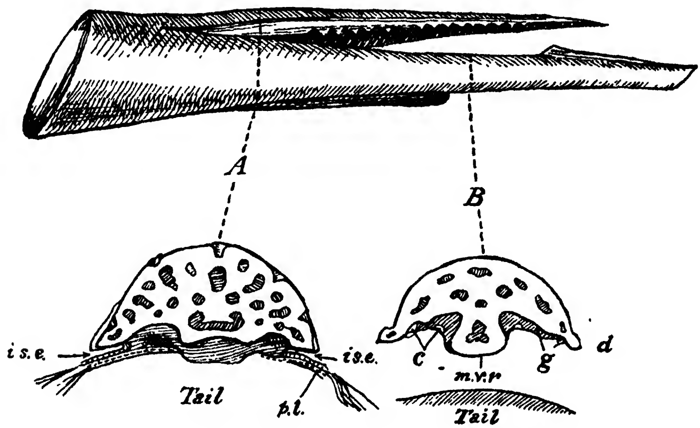


Fig. 12. Portion of the tail of Sting-ray showing the origin of the caudal spine. The whip-like tip has been cut off.
Below are two sections of the spine at the levels *A* and *B*. At *A* the section is almost hemispherical and an invagination of superficial epithelium is seen on either side joining the epithelium of the lateral grooves.
At *B* the spine is separated from the tail and is flatter in section and shows a median ridge *m.v.r.*: *d*, the tips of two teeth of the dentate margin: *g*, points to the gland of the groove: and *c*, to the lateral canals.

cuttlefish has therefore a protective device for rendering itself invisible and an offensive weapon for paralysing its decapod prey. We will consider first the inky secretion discharged by most cephalopods, which has been proved to consist of melanin, a substance used by artists to obtain a brown or black colour. Melanin is related chemically to a substance called tyrosin which may be formed in the degradation of proteins. In cuttlefish however it is produced by the action of an enzyme or

ferment known as tyrosinase on tyrosine. Turning from these chemical reactions to the formation of the crab poison we find that it can be extracted by alcohol from the posterior salivary glands and that it is a substance known as tyramine (Para-hydroxy-phenyl-ethyl-amine) which can be produced from tyrosine by the removal of carbon dioxide in the putrefaction

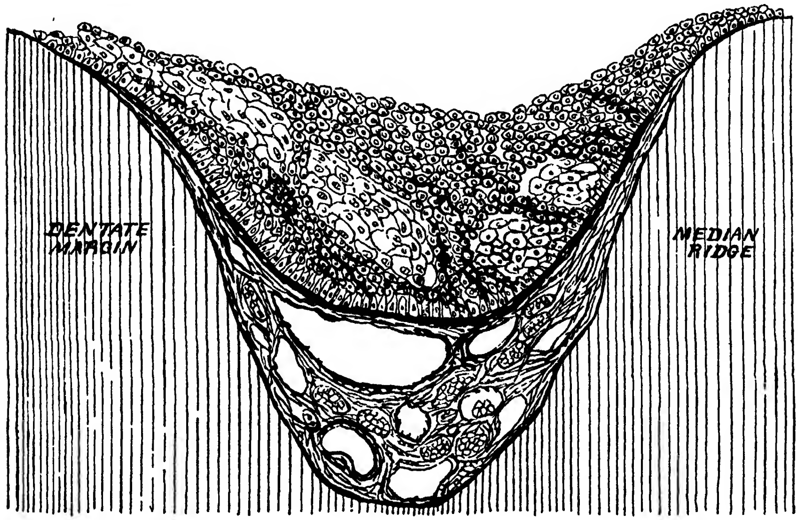


Fig. 13. A section of one lateral groove showing the superficial glandular portion in a state of active secretion, and the layer of pigmented capillaries dividing it from the deep alveolar part with one large and several small canals.

of meat. To those who have no knowledge of chemistry this alchemy of organic compounds must sound like magic; the transformation of a pigment into a powerful poison suggests the occult. But a simple everyday example may be cited and seen by observing what takes place in a coal fire in an open grate. If the draught, that is the supply of oxygen, is not sufficient, the imperfect combustion of coal produces gaseous fumes rendered visible by small particles of carbon: in short, the fire smokes and soot collects in the chimney. But when the

combustion is more complete, carbon monoxide may be formed which burns with a blue flame to produce carbonic acid gas, which is carbon dioxide. The simple addition of more or less oxygen in the combustion makes all the difference between a cloud of smoke and a gas which is a deadly poison to man, namely carbon monoxide.

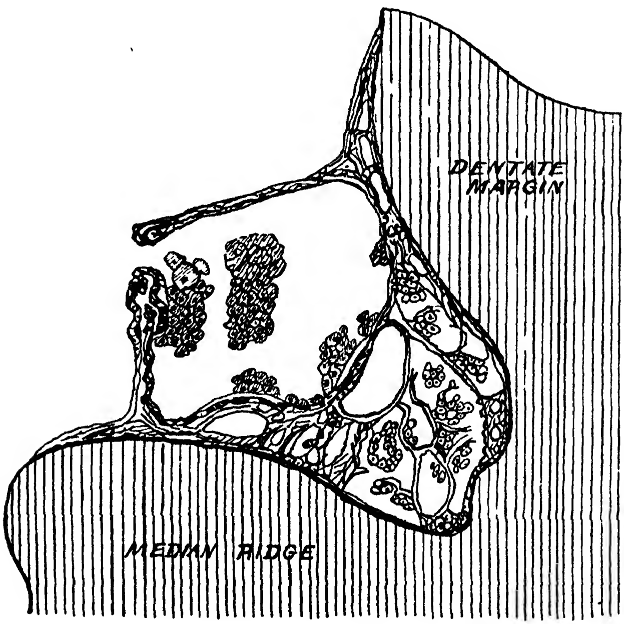


Fig. 14. The lateral groove of the spine nearer the tip. Portions of detached epithelial tissue lie free and attached to the pigmented layer. The gland is protected by two lateral flaps containing pigmented capillaries. The deeper portion has a large central canal and blood-vessels.

The isolation of tyramine is an example of the importance of little hints which may appear insignificant. Mme Phisalix records how Baglioni compared the symptoms produced by crab-poison with those resulting from administration of carbolic acid to a frog and suggested that the saliva of the

octopus contained a phenyl derivative. This was truly prophetic for we recognize the phenyl in parahydroxyphenylethylamine which was investigated by Barger and Dale.

There can be little doubt that in the light of the above facts we are justified in attributing to the black pigment found in the epithelial gland of the sting-ray the function of a reserve of

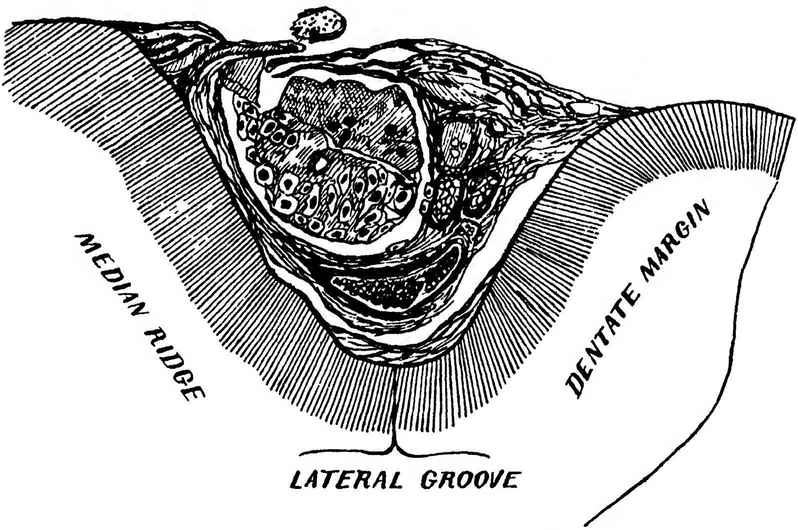


Fig. 15. A section of the tip of the spine of a Malayan Sting-ray. The epithelial portion has been retained in position intact. The lateral flaps completely enclose the gland and some secretion is seen being discharged. The central canal is also present with its pigmented wall.

waste products about to be transformed into a poisonous secretion.

We can take another hint from the above observations of the nature of the crab poison of cephalopods. In the first place the similarity of the diet of the cephalopods and the sting-rays must be noted. A crustacean diet of crabs is common to both. When the nature of crab-poison is investigated we find that the effect produced on crabs is not confined to crustacea but that it is also capable of causing venomous effects on other animals

including vertebrates. It is above all a selective poison of the nervous system, producing convulsions followed by paralysis, as has been proved by experiments on the frog and rabbit.

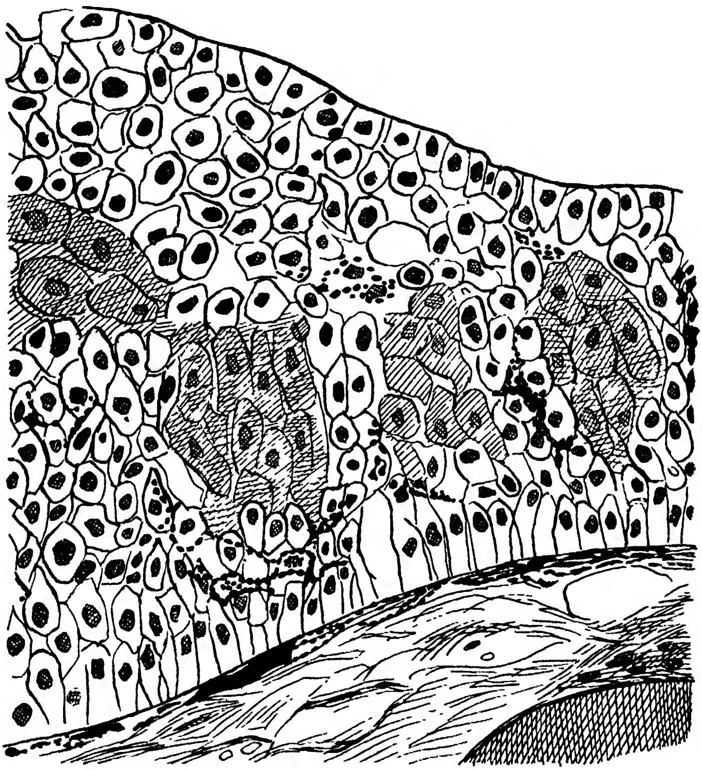
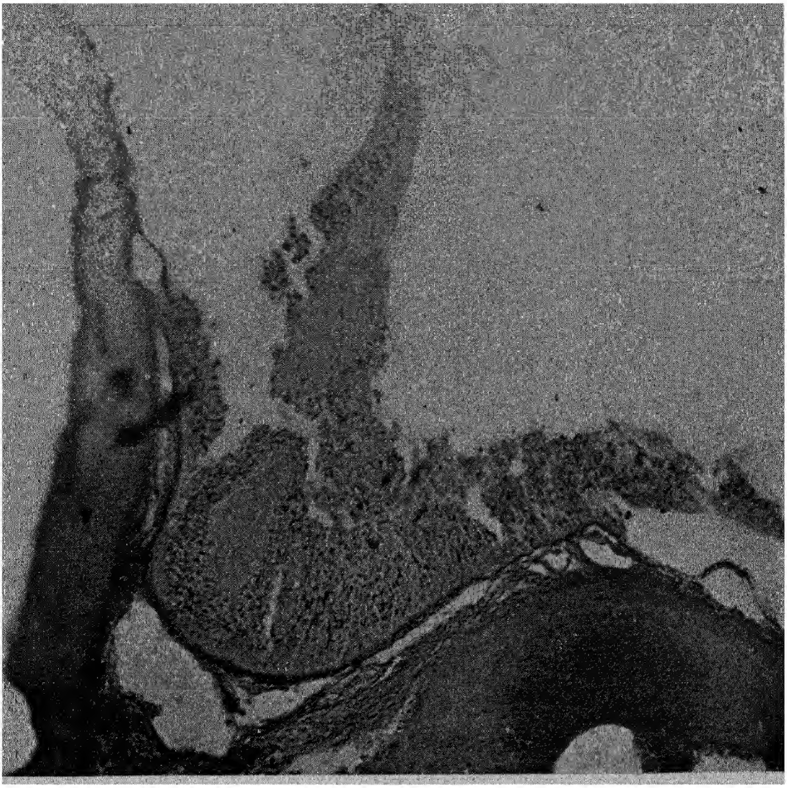


Fig. 16. Section under very high power of the glandular epithelium of the groove of the spine of Sting-ray.
Note the columns of elongated cells resting on a pigmented layer; the more superficial are seen undergoing changes of outline as they form the secretion: black pigment granules on their margins are also seen.

The history of the accidents to human beings that we recounted in detail and the cases of poisoning described by earlier writers all point to the conclusion that the poison of sting-rays is a powerful neurotoxic venom, apparently very

similar to crab poison. Unfortunately this conclusion cannot readily be proved experimentally. It could of course be carried out in such an institution as the Aquarium of Naples but in the confused state of the Continent we must be content to leave the matter as it is.

We have mentioned above that great difficulty has faced many workers in obtaining complete sections for microscopic examination. For the guidance of any future workers, I would suggest that the method adopted by the late Dr. Albert Gray in his investigations on the cochlea should be tried; it seems to me that this method would prevent any distortion or loss of tissue elements. The following is an outline of the process. 'After preliminary treatment the portion of bone was placed in melting wax and kept at a temperature of 50° C. for a week or so. Thereafter the whole was allowed to cool—the wax was now carefully scraped from the outer surface of the bone, which was eventually placed into very dilute hydrochloric acid.' The chance of the epithelium falling away in the course of decalcification is thus avoided (*The Basis of Tissue Evolution*, Glasgow 1937). The spine of *Trygon* is most adaptable to this technique.



. PLATE V

The gland of the groove of the caudal spine of the Sting-ray (low power). A tapering mass of cells is separated from its attachment to a portion of the toothed margin, and the main portion of the gland lies in the deep part of the groove but is partially detached from the median ridge.

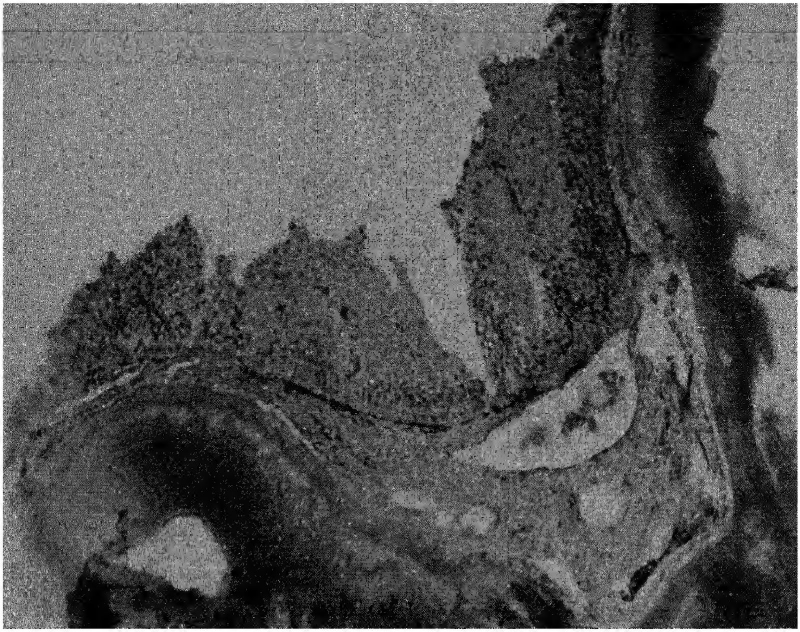


PLATE VI

SECTION OF CAUDAL SPINE OF THE STING-RAY, SHOWING A LATERAL GROOVE WITH GLAND

The gland of the groove (low power). The gland, part of which is in an active stage of secretion, rests on a pigmented layer, which separates it from an alveolar area and a large central canal containing amorphous matter.

Chapter 6

BLACK AND WHITE: FISHES OF THE DEPTHS

Any morning in the spring, when the sun is well above the horizon, a visitor to Madeira may see sailing from the fishing port of Cama de Lobos a long and graceful fishing boat with bold Phoenician prow and pointed stern, carrying a long-yarded lugsail, or driven by rows of sweeps. She is making for the fish market of Funchal and the harbour from which she has sailed may be known from the paintwork on her sleek carvel-built sides. A boat may be painted white with topsides of orange and below a deep blue, while another has red topsides separated from a sea-green bottom by a band of orange. Each port in the island has its sailor's signature design, a medley of brilliant colours, beloved by the Portuguese pescadores. As the boat draws nigh to the bathing pools of Funchal, it passes a volcanic cliff jagged and rugged with masses of rocks, with bits of green weed picking out the red-brown from the orange sunlit patches, and purple shadows; here a short distance from the shore stands a pinnacle of rock rising from a foam-washed base, encircled by the white swell breaking on the bastion. Between this massive monument and the shore the fishing vessel bows to an off-shore breeze and races on to the harbour, with its constant changing fleet of liners and ships of all nations. After breakfast, at which one first meets the inevitable 'Espada', a walk down the town will take one past villas with tropical gardens and southern scents, and so past the shops with their bright colours, past the market with attractive flowers and fruits and thence a few yards bring the traveller to the fish-market, where a state of clean-

liness and coolness, under a large roofed building with open sides, greets one with sanitary satisfaction and surprise, while running water cleans the slimy slabs. One had heard of the wonders of Funchal in Richard Lowe's *Fishes of Madeira* and Günther had told of the small-spined shark (*Centrophorus*) which lives at greater depths than any other known shark. 'The Portuguese fish for them in 400 to 500 fathoms with lines of some 600 fathoms in length.' These sharks, which may be from three to four feet long, when hauled into the boat fell down into it like so many dead pigs; there was not the smallest motion of their bodies. There is little doubt that they were killed by being dragged to the surface from the immense pressure of water in which they normally lived.

But my journey to Madeira was not for the purpose of studying sharks; the fish arrayed on the slabs, or being cut up, and sold, were a sudden revelation of the variety in size and form and diversity of coloration in these southern seas. Roughly they represented dwellers near the surface and dwellers in the depths or even sojourners in the abyss. The first group was headed by the vast tunny, the red flesh was being carved up into slabs of 'raw steak'; then there were numbers of the mackerel family, horse mackerel and many others with the characteristic scombroid form and bifurcate tail, many attractively coloured. But there is no need to enumerate the various species, because all eyes are at once focused on a deep-sea fish which monopolized a corner of the market. Picture to yourself a long snaky-looking animal, as jet black as black patent-leather, of the shape of a flattened inner tube of a motor tyre, ending with the head of the greyhound form, with wide gape and monstrous long teeth, and enormous eyes, and the tiny bifurcate fin attached to the tapering tail. The fins are represented by a long dorsal fringe, extending from the level of the gills to the tail, divided into two nearly equal parts. The above description makes this fish sufficiently unique, but in addition it carries a curious dagger-like spine behind the vent. Cesar de Noronha published a

monograph in Portuguese (1925) on the Black Scabbard fish which is little known and this is what he says: 'Near the anal orifice is a terrible offensive weapon consisting of a short strong spine imbedded in *certa mucosidada venenosa.*' My own observation recalls the dagger-like spine of the operculum of the weever, but I regret to say that world conditions have prevented me from demonstrating a poison gland, of the existence of which there can be little doubt. My fascination by this fish soon attracted the native onlookers, and my attention was called to the dagger by a fisherman who proceeded to show me his scarred and maimed hand, the result of its stab. The effects of this sting appeared to be very distressing, and in all cases the pain seems to have been characteristic of a fish's sting. The author just mentioned relates that death may result through complications aggravated by the mucus which invests the spine. A point that seems important to notice is the extreme oiliness of this fish and others taken at great depths, which may have great value in providing resistance to great outside pressure.

We must now mention an organ, the swim-bladder, which is found in bony fishes but not in sharks, and we must stress this point as the shark above mentioned, one of the Dogfish family, although not possessing this organ, is just as distressed as a fish like the Black Scabbard fish, which does possess one, when it is drawn up suddenly from a great depth. Old writers, like John Hunter, talk of an air-bag, but it would be more correct to say gas-bag, which does not commit one to the nature of the gases. The swim-bladder is situated in the upper part of the abdominal cavity, and may be completely closed or have a short tube or duct communicating with the gullet; the latter is mostly found in fresh-water fishes, such as the Carps, and the problem of how these fishes get their bags distended with gas has only recently been explained. Captain G. C. C. Damant, the famous naval expert in all that pertains to diving, has collaborated with me in solving the problem. It is now known that Carps come up to the surface, swallow air and pump it

into their gas-bladder by a special pump, the pneumatic bulb; if however they are prevented from coming to the surface, they are able to fill the bladder by secreting gas by means of the lining membrane of the bladder, which is furnished with a fan-like mesh of blood-vessels over its whole surface. However, in those fish with closed swim-bladders, these blood-vessels are confined to a small area which is like a sponge-work of blood-vessels lined throughout with a specialized epithelium and known as red-bodies or gas-glands. The composition of the gases varies according to the habitat of a fish. In surface fishes the gas only consists of a small proportion of oxygen, but in deep-sea fish the gas is nearly pure oxygen, in some cases as much as 87 per cent of the whole. In marine fish the hydrostatic function of the swim-bladder is its chief use. It enables a fish to maintain a neutral buoyancy; that is to say it can float at any depth without effort. As a fish descends the pressure increases, and the gases being compressed, the volume of the fish becomes smaller and it tends to sink. This tendency can be remedied by the gas gland producing more gas. But if a fish rises from a low level the gas expands and goes on doing so as it rises further. This again is countered by either letting gas out through the duct, or by the absorption of gas by a special area, called the oval, which can be closed or opened at will.

Owing to the depth at which the Black Scabbard fish is caught by the long lines of the Portuguese, it is not surprising that the fish are brought to the surface nearly if not actually dead. Moreover as they possess an air-bladder or swim-bladder the expansion of the gases within this organ is so great that the stomach and intestines are extruded. Different observers disagree as to the depth at which this fish lives, but from enquiries I made from the curator of the local Museum it is held to be from 600 to 1,600 metres. In addition to the poisoned dagger, the Black Scabbard fish is reputed to have venomous teeth and a bite produces profuse bleeding, as the saliva contains some anti-clotting ferment just as does that of the leech. How does this monstrous fish with this aggressive armament find

its prey in depths of half a mile or so? I remember as a boy, in the unregenerate days of the Thames Conservancy, watching the bottom fishermen clustering at a spot just below Richmond Bridge where the sewer sluiced into the sweet waters of the Thames. It was here the coarse fish congregated, and it was here that sport was good. I suggest that the small fish gather round the Scabbard's vent and there get stung and thus become a ready prey to its sharp and deadly fangs. There is little more that can be told of the habits of this fish, as the absence of stomach contents makes a study of its diet impossible. But we can still find out some new facts by a neurological study. It has been shown through my studies of the different species of the Cod family (*Cadidae*) that the hind brain varies with their diet and habitat: in certain fish with aids to hearing such as the herring and some carps there is an area of the brain highly developed which is poorly developed in others not so endowed. In deep-sea fishes hearing does not come into the picture, but another area of the hind-brain called the lateral-acoustic area becomes very large and important, and it is connected with the development of the organs of the lateral line. The hake is a good example of this enlarged lateral acoustic area and it lives in the deep water of the Atlantic shelf, while in contrast its cousins the Cods have not this enlargement. It was the study of the brains of deep-sea fish that led me to Madeira and here my conclusions were confirmed, and I found a very remarkable development of the lateral area in the Black Scabbard, which shows it to be a bathypelagic fish, predaceous and living in very deep water, but not an abyssal fish.

But this vicious fish with its deadly dagger and fearsome fangs is after all a god-send to the poor people of Madeira. Both its flesh and its oil are valuable and any day in the poorer parts of the town the children may be seen carrying home a *peixe espada preto* with its tail tucked through the sockets of the huge eyes, reminding one of the homely whiting. The hotel keepers, both indigenous and English, have reaped vast

sums from its value as a table dish, as it is capable of being served up in attractive forms by a clever cook and it is *cheap*.

In sharp contrast to the Black Scabbard fish is the true Scabbard fish or White Scabbard, no less characteristic of the Madeira markets. It is a beautiful glistening white fish with no scales but clothed with silver tissue and, unlike the black demon, has no dagger-like spine. Its gape and its teeth are still formidable, for even beautiful creatures must feed. It is a gregarious and roving fish and is found from Norway to the Cape of Good Hope and extends as far as New Zealand and the Atlantic coast of America. It is found near the surface and also at a depth of 300 metres and is a very fast swimmer. A curious habit of this fish has given it the name of 'frost fish' in New Zealand; on cold nights it has been known in vast numbers to swim towards the shore, and there is heaped up a ridge of corpses. This is said to be due to the effect of cold but this is unlikely because it has not been known to behave thus in Norwegian waters. Further, the effect of cold on fish is usually to make them seek deeper waters, as is well known from the sole's habits. I think a more reasonable explanation is that we have here an example of the mass migratory immolation that has been described in lemmings and springbuck. The latter is less known than the lemming. In 1890 when I was working in the Orange Free State the veldt teemed with herds of springbuck and in days long gone by they roamed in countless multitudes over the vast plains of South Africa. Their true home is the Kalahari desert and Damaraland and they are noted for their remarkable speed and jumping powers. As a rule herds are confined to their own territory and when they migrate they avoid other people's territory. Two years before my sojourn Scully described the springbuck of Bushman Land, an arid desert lying south of the Orange River some 300 miles from the Atlantic, a chain of arid mountains intervening. The only human beings who venture here are the Trek-Boers. Though this country is separated from the sea by a rugged ridge, a huge migration takes place towards the coast from

which none return, and such migrations recur once or twice in every twenty years. A continuous column has been seen taking days to pass in which stragglers fall by the way, but yet the mass still heads over rugged mountains to the sea, into which the buck finally plunge and drown. On a desolate stretch of sandy shore piled-up hordes have been seen, making a continuous bank of dead bodies for thirty miles. It has been noticed that when about to undertake this strange pilgrimage the springbuck changes its character and from being the most timid of animals becomes quite fearless. If we now transpose the animals and the conditions we can trace the similarity of the phenomena and observe the silvery Scabbard fish in its multitudes seized by some strange urge to drive on towards some unknown goal from which no obstacle, land or sea, can divert or obstruct. And the final result is the same both in the terrestrial and the aquatic animal: a holocaust of swollen corpses spreading miles along the shore.

The contrast between black and white and dagger or unarmed is not confined to the two species we have just been considering, as we see when we study other Scombroids from similar habitats. A fish often confused with the Black Scabbard by the Portuguese fishermen is a long black fish with conical cartilaginous projections from nose and lower jaw (*Nesiarchus nasutus*). This has a stout two-edged broad anal spine. On the other hand a very long silvery fish not unlike the Silver Scabbard fish has no dagger (*Benthodesmos elongatus*). Again *Promethichthys prometheus* is slender and of a silvery grey colour, living in very deep water; this fish, known as 'Coelho' or 'Rabbit' fish, has no anal dagger. Other examples might be given which would be only tedious, but it seems to be clearly established that the fishes with this formidable dagger are always 'in sombre harness mailed', while the fair and silvery fish are unarmed. An explanation of this phenomenon which would bring conviction to a biologist has not yet been brought forward, although it has been suggested that the depth at which the fish live might be the cause of the variation.

Chapter 7

SCORPION FISHES

In a *Naturalist's Voyage round the World*, written somewhere about 1840 (the second edition containing a preface dated 1845), Charles Darwin describes how, passing round the northern end of Mauritius, he was struck by the beauty of the island, and the bright green fields of sugarcane on the sloping plain of Pamplemousses, interspersed with scattered houses, while wooded mountains rose out of the highly cultivated plain, their summits jagged like the usual volcanic peaks.

My approach was from the south-west. The *Conway Castle* had sailed from Durban and after passing the southern end of Madagascar had coasted for two days within sight of land but not near enough to make out anything except the general features of the country. At night we had witnessed the most majestic and awe-inspiring lightning which seemed to envelop the whole land in flames, while distant thunder rolled down the mountain sides. This unforgettable scene was not just a passing storm but continued far into the night and the spell-bound passengers remained on deck until the small hours. We came to anchor and lay off the town of Tamatave in the roadstead, as there is no real harbour, and the so-called town was reached by a trolley track for small trucks over a stretch of loose sand. Besides the native population there were a few agents of large commercial houses, and several missionaries; the former were only too glad to come aboard and forget the interminable monotony of their soul-less existence. We lay here for several days, while Malagasy cattle were driven down to the shore and swam off to the ship towed behind lighters; when alongside the ship, slings were passed under

their bellies and they were hoisted on deck by derricks, and then penned on the fore-deck. With this valuable cargo and other foodstuffs on board we sailed for Mauritius, but as we reached Port Louis at night we were unable to join with Darwin in admiration of the view. Here I was fortunate in having relations, and by making arrangements with the regimental medical officer of the garrison, I was able to live ashore at Curepipe, in the hills, going down each morning to do duty till the afternoon. In this way I was able to get well acquainted with the island and its people, and to study its natural history.

Darwin seems to have been most interested in volcanoes and corals during his stay in the island, and he makes no mention of its fish. On the other hand he made some interesting observations on what are now known popularly as stinging corals. He says 'I was a good deal surprised by finding two species of coral of the genus Millepora possessed of the power of stinging . . . one day by merely touching my face with one of the branches pain was instantaneously caused; it increased as usual after a few seconds and remaining sharp for some minutes was perceptible for half an hour afterwards. The sensation was as bad as that from a nettle but more like that caused by Physalia, or Portuguese man-of-war. Little red spots were produced on the tender skin of the arm, which appeared as if they would have formed watery pustules, but did not.'

The progress of marine biology has explained the mystery of this stinging property of certain corals. To quote Russell and Yonge in *The Seas*, 'one of the corals called Millepora is found in coral reefs all over the world. It has two kinds of polyps which have a perfectly definite arrangement. If a piece of the whitened stony skeleton of this coral be examined it will be found to be covered with a series of fine apertures each consisting of a central opening surrounded by a ring of from five to seven smaller ones. The former is occupied in life by a relatively stout stumpy polyp, which has a mouth and a diges-

tive cavity, while through the smaller project long slender structures each with a series of little tentacles from the main axis. These are all without mouths, but have batteries of stinging cells with which to paralyse the minute animals on which they feed.' They can penetrate the human skin and cause a painful nettle-rash. Darwin continues that besides the jelly-fish the Sea Hare (Aplysia) of the Cape Verde Islands, an actinia, as well as a flexible coralline allied to Sertularia, possess this means of offence and defence and that in the East Indian Sea a stinging sea-weed is said to be found. The reason why the well-known Sea-scorpion, Synanceia, was not mentioned by Darwin is that at the time of the voyage of the Beagle the nature of this fish had not been noted by Europeans. It was only in 1845 that Clarke described a case of severe symptoms following the prick of Synanceia. In 1864 Nadeau gave the first description of the poison organ of this fish, known in Tahiti as 'Noho'; and in 1870 le Juge described the death of a fisherman from a sting after three days.

Walking along the sea-coast to the north of Port Louis an uncultivated plain is reached, consisting of black lava covered with coarse grass and scrub, and where the sea encroaches on the rocks at high tide are rock-bound pools and occasional patches of sand, near which grows the plant used by the natives as a cure for the stings of the Poison-fish Synanceia; this is known as *Abrus precatorius*, and my observations on this antidote will be described later. The rocks on the sandy foreshore are covered with waving fronds of brilliantly coloured seaweed with tints ranging from olive-green to orange and scarlet. In the deep clefts is a gorgeously coloured rock garden of star-fish, sea-anemones, sea urchins, and strange worms and crustacea, while lurking in the crevices lies the watchful Synanceia, wearing a motley of fantastic colours which blend and harmonize with the gay garden scene, while the stripes on fins and body conceal it from its enemies as well as from its prey. The strange denizens of these groves and grottoes are of a most grotesque and bizarre appearance, often

forbidding and even frightening. So often is this the case that fishes have received their names from their disfigurements. For instance Synanceia is known to the natives of Réunion as '*Crapaud de mer* or sea-toad', and in Java it is known as 'Ikan Satan or devil-fish', and in Tahiti as 'Nohu or Noho'. It is never found in deep waters, but makes its home in the rock gardens or buried in the sand. It is a stumpy fish with a large head and prominent eyes and its warty skin has given rise to its appellation *verrucosa* or warty ghoul. The mouth has an

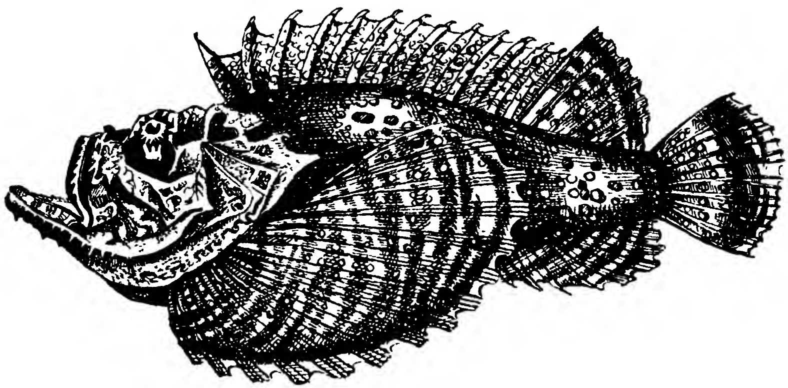


Fig. 17. *Synanceia Verrucosa* (After Savtschenko)

almost vertical gape. The bulging pectoral fins striped with vertical lines are bordered with tiny tags. The spinous dorsal fin has fifteen rays and the small soft-rayed fin behind it has transverse markings. The tail is small and fan-shaped while the anal fin is a replica of the soft dorsal. It may well be asked why such an ugly brute inhabits scenes of such beauty. This can best be answered by considering what is beauty, and on what does it depend. It is an abstract character the existence of which is inherent in the mind of man, just as is the knowledge of good and evil. It depends on such conditions as harmony in colour, sound and pattern, and in symmetry of form and movement. A graceful form and a graceful movement is at once recognized even if it is seen in such different forms of life as the gliding

movements of an eel, or the dancing of a Pavlova. Disharmony of form is obvious in the tadpole with its large body and disproportionate tail, but it is not forbidding, whereas the gross head and corpulent body of the toad with its bandy hind-legs and ungainly movements are an ugly and loathsome sight, to which Nature, to complete the unlovely picture, has added poisonous skin-glands and an offensive slime.

The toad-fish is therefore ugly to the eye and mind of man; but is it to the eye of a fish? It is probable that it is seldom seen by its enemies and never seen by its prey, for its coloration and stripes are so useful to the concealment of its presence, that any unwary small fish is engulfed in the large gaping mouth in a split second. The irregular outline and the tags also help to obliterate and so protect the fish. The similarity to the toad does not end with its ugliness as both fish and batrachian have poison-glands which secrete very similar venoms. But whereas the toad carries its poison in the parotid and skin glands, Synanceia has a very highly developed poison apparatus in connection with its dorsal spines. Each spine has a deep groove on either side and towards the middle of the spine lies a pear-shaped bag about the size of a small pea which is prolonged distally into fine ducts which discharge the venom into the tip of the groove, but only when the bag is subjected to pressure; in fact the expulsion of the venom is not voluntary. The effect of a sting from Synanceia is even more painful than that of a weever. It is described as atrocious and spreading up the limb of the part attacked. Calmette says 'he has seen a man, recently stung, become delirious, hitting and biting anyone near him, throwing himself from one side to another and insisting that the injured part be cut off'. People have been known to amputate the wounded part themselves. Faintness and profound collapse often occur, sometimes followed by death. If the patient recovers from the syncope there may follow an acute inflammation of the soft parts, which may be accompanied by septicaemia, and the inflammation may end in local gangrene and sloughing of the part. When the dead

part has separated, which is a slow process, healing may commence but this is also very slow. The worst cases are those that have been stung in the sole of the foot when paddling or hauling in a seine net, as the victim gets the full contents of the bag injected by the pressure of the foot. It is clear from

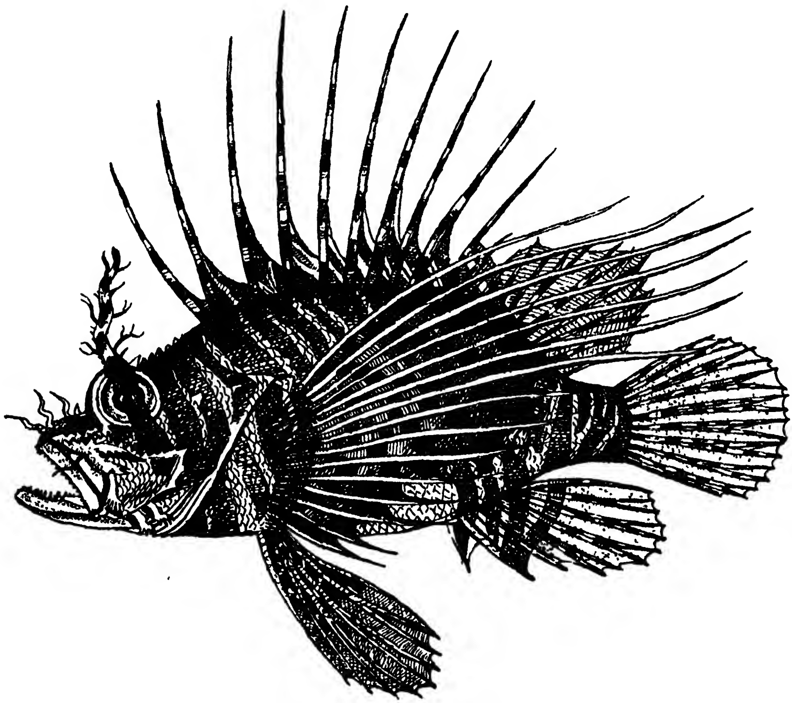


Fig. 18. *Pterois artemata* (After Savtschenko)

this description that the poison of Synanceia produces the same symptoms as those of the weever, only more acute, and this is probably due to the larger dose of venom injected by the former fish with its reservoir of poison.

Three fishes of this group may now be considered together as they have many points in common. *Pterois artemata* unlike Synanceia is not repulsive to look at; in fact it is quaint and fantastic rather than grotesque, and perhaps the adjective

picturesque best describes this frilly-looking fish. Its descriptive name artemata refers to the extended fin-rays, and these elongated rays are found both in the dorsal and pectoral fins, which when extended produce the effect of a fan, and so conceal the striped body. The free portions of the dorsal spines are further decorated by alternate light and dark markings. The eyes are very prominent and their upper margin extends considerably above the line of the head. We have mentioned the body stripes which are vertical, but one broad dark stripe extends up to the eye and then is continued from the upper margin of the eye on to a sinuous tentacle, transversely marked and with a hairy surface. There are a few longer hairs on the head in front of the eye. The mouth is large but has not the upward gape of Synanceia, while the margin of the gill-cover is prolonged into an acute angle. The dorsal spines are known to be venomous but what is the protective value of this elaboration of the spines into antennae and what is the function of the filament in front of the eyes?

In our description of the under-water seascape in tropical waters the sea-fans were not mentioned in particular, but they are one of the most beautiful coralline formations in many tropical seas. They are technically known as Gorgonids and are said to form beautiful pink-coloured miniature forests. These fans grow in one plane from a stalk attached to a rock and spread out radially in many branched fronds. Against this background *Pterois artemata* spreads its fan, and its colour from a dull red to a rose pink blends with the pink of Gorgonia.

The waving preorbital filament has no doubt the function of a lure. The site is that of a lure and its apparent connection with the eyes makes its appeal to a small fish irresistible. Larval fish show little but an eye and a few filaments, as for instance the larval stage of a Fishing Frog, and in the larval stage many crustacea are often only seen as floating eyes. It would appear reasonable to conclude that Pterois lies hidden and awaits its prey which receives a paralysing sting from the dorsal spines

before being swallowed. The mention of fan-stars recalls the fact that one species is known as *Gorgonia verrucosa* or the warty one, which curiously enough is the descriptive name of Synanceia, the skin of which is studded with small excrescences; the presence of small polyps on the branches of a sea-fan might be the origin of this name, which otherwise would seem inapt.

Pelor the 'pop-eyed' is a sort of halfway house between Synanceia and Pterois; the form is more repulsive even than that of the former. The skin is loose, flabby, and gored with fleshy tags. The dorsal and pectoral fin-spines are elongated but not to so great extent as those of Pterois, and the dorsal spines are furnished at intervals with a row of spicules; these make the picture of Pelor portray a background of Gorgonids, especially certain brittle and feather stars with small lateral branches similar to the spicules of Pelor, and as has been said by Thayer all highly patterned fishes wear real background pictures. Another generalization is that the gaudiest tropical fish are coloured for concealment. The eyes of Pelor are so prominent that they stand up above the line of the head like two navigating lights on the bow of a small vessel, and the dorsal fin extends so far towards the eyes that there is no room for a lure; the deep depression in front of the eyes gives the whole fish a disfiguring and revolting appearance, and the spiny margin of the gill-cover increases its dangerous aspect. In comparison with Pterois its coloration suggests a more active life; the back is dark and shades into pale yellow on the ventral surface, thus providing protective obliterative shading; while the soft dorsal has striped markings, the anal is inconspicuous. The significance of the markings on the caudal fin will be left till we have described the fin markings of Scorpaena.

The descriptions of Synanceia, Pterois, and Pelor have shown the value of the study of the markings of a fish if we wish to understand their habits and mode of hunting. Another family of Scorpaenidae will also repay a detailed study of the mark-

ings of these venomous fish. They have large heads, scaly bodies, and are highly coloured, while the dorsal fin is single and consists of eleven spinous rays and seven soft rays. They are all more or less bizarre and grotesque while Scorpaena vies with Synanceia in its repulsive appearance. *S. grandicornis* with its red back and yellow eyes and belly is yet obliteratively shaded, and the dark tone of the back extends to the upper

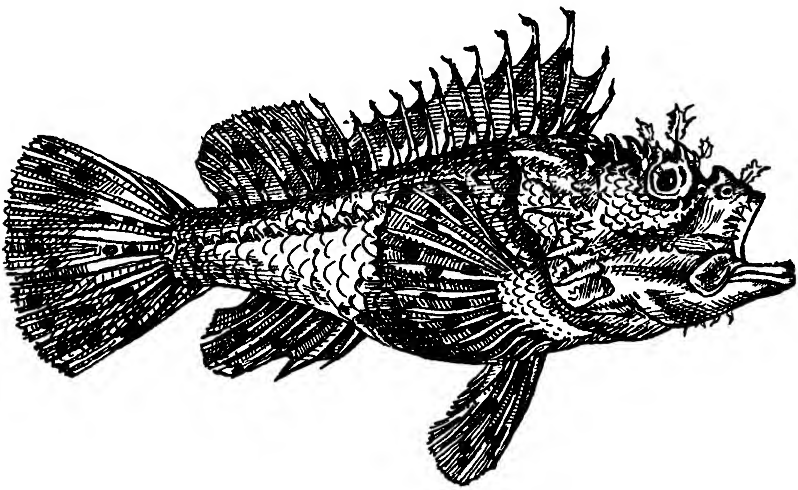


Fig. 19. *Scorpaena scrofa* (After Day)

part of the pectoral fin, which also shows a dark circular spot or ocellus, the size of the eye, on its lower yellowish portion. This ocellus is repeated by two spots on the posterior part of the body towards the hinder end of the dorsal fin. These spots have the 'dazzle' value which is so well known on the wings of birds and butterflies. The soft rays of the dorsal fin form a wing-like structure with a broad dark margin, separated from a less dark band at its base by a light area; the anal fin is marked in a corresponding manner. The tail has obliterative markings, two light areas separating three broad, dark, vertical bands.

The body is shaped for speed, not unlike a tunny's; the

mouth is large and the prominent eyes extend above the line of the head and just in front is a two-horned tentacle, branched like a bit of sea-weed. We gather from the form and the shading that this fish is not sedentary. It has a predatory mouth and its dazzle markings and marks on tail and fins all point to movement and not to any background mimicry. This fish is found in the Caribbean Sea and Beebe describes how he was stung by a small specimen which had been stunned by one of his explosive caps; it was brilliant red and not near the bottom. The sting was like that of a wasp but more severe.

Chapter 8

NORTHERN LATITUDES

The wise traveller to Norway will have no doubt as to the best route to take if he wishes to visit the fjords. The world-famous motor vessel *Venus*, the fastest vessel crossing the North Sea to Bergen, takes less than twenty-four hours and, after a comfortable night on board, the ship is passing the numerous islands on the approach to port in the afternoon, and the passengers are landed by tea-time. Wandering round the port and the fish market during the morning, the most striking thing noticed is the callous attitude the Norwegian has towards fish; on the quays are to be seen large tanks full of fish awaiting the housewife, who selects from its prison the desired fish which, with no preliminary whack on the head, is promptly gutted and skinned and even filleted. But the Englishman has no right to be critical, as I have often seen soles skinned alive on our own markets and the lobster is still boiled alive. Nevertheless the scientist is not permitted to inoculate a fish, for the purpose of investigating a venom, without a licence from the Home Office which insists that the experiment must be conducted in an approved Institution. I suppose it was the contrast that upset my equanimity, but amidst all the beauty of Bergen and its surroundings it was a shock to see the slimy shambles or slaughter tanks on a lovely summer morning and to watch the death struggles of the uncomplaining fish. This is not the place to discuss the subject of the sensation of pain in fish, which I have raised elsewhere, but the naked nerve-endings that are responsible for toothache in man are also present in fish, and if pain is a protective mechanism it would be reasonable to expect that it had de-

veloped in all vertebrates and not only those that have become terrestrial in their habitat.

A casual glance at the fish for sale did not reveal any fish that one might not see in a large market at home, although one was struck by the numerous specimens of the Norway pout and the Coal-fish. It was not until I got to Trondjheim that I came across any specimens of the Bergylt or the Norway haddock, the natural history of which I was particularly keen to study. Before going north by coastal steamer the lake-like Hardanger Fjord was visited. Large tourist steamers surprise the chance dweller in a small village on the shore by suddenly making fast to the shoe-scrapers at the front door, whence a horde of travellers suddenly invade the small dining room. Nevertheless the outlook is that of a Swiss lake.

It was a lovely summer's day when I looked from my verandah over the fjord and drank my morning coffee in my pyjamas. Cultivated fields occasionally led down to the water's edge where several islands jettied into the lake, but the slopes were mostly wooded or cloaked with clumps of fir. Both shores met in the mid-distance where the tortuous waters seemed to be blocked by brown foothills which were topped by forests, hazy blue in the distance, which led up to grey mountains, their summits shining in the everlasting snow. In such peaceful scenes I spent a lazy Sunday paddling about in a rowboat or loafing in the flower-scented garden while the inhabitants, who had donned their native costumes in honour of the visiting ship, relapsed into shorts, flannels, and sleeveless cotton frocks. Travelling north by steamer to Trondjheim one is soon introduced to what is the more typical scenery of Norway; a recurrent view of one of the deeper fjords may be described as a vista of grim precipitous cliff rising straight from depths, often half a mile down. But the lights and reflections in unruffled waters add romance to the sadness of harsh rock and dark forest. On the left may lie a perpendicular black cliff which is mirrored in the water as polished malachite, while the rest of the fjord is pale blue with faint reflections of less

severe hills on the opposite shore. In the distance where the two shores seem to meet, but actually wind away to the left, appears a sugarloaf hill, a truncated cone of a grey stone, which seems to be ubiquitous, and from the cliffs which partially conceal it, several waterfalls tumble, spreading into glistening spray and often making special rainbows by prismatic magic; and crowning this manifestation of the magnificence of mountain are the snow-clad peaks shining against an unclouded sky. Such is the scene to delight the eye of the most jaded traveller, but it is beyond description to portray the horrid forms and weird reverberating sounds with which these same jagged mountains may fill the valleys on a wild winter's night. But in the unfathomed depths of these fjords, which, passing from the sea, may burrow even a hundred miles into this tremendous land, are fish which are rarely seen except by the fishermen who cast their long lines into the adjacent seas, and some which never would be seen unless they strayed within the orbit of one of the maelstroms, the fatal Norwegian whirlpools, and were eddied to the surface.

The Norway Haddock, Bergylt or *Sebastes norvegicus*, is a member of the Scorpaenidae but differs in many ways from the Scorpion fishes of warmer climates. It is found at great depths, eighty fathoms or more off the coasts of Norway. It seems that there may be two species of Sebastes, one, the smaller, found in the fjords, and the other in the seas around the Faroes and even as far as Greenland, where it is said to grow to a very large size, weighing as much as twenty pounds. Its name of haddock is curiously inappropriate, as its form is more like that of a perch. Its head is armed and scaly even beyond the orbits. Its only similarity to the haddock is in its diet, which is mostly crustacea, molluscs, and small fish. That it is usually a bottom dweller is proved by its colour, which is uniformly a bright vermilion, being only slightly less brilliant on its lower surface. From this marked coloration it was sometimes called 'soldier' by cockney fishmongers, before khaki was the prevailing uniform. It is well known that if a number of

pieces of unglazed paper are coloured in various bright tints and laid on a black ground, and the light gradually turned down, the red colour is the first to disappear or become neutral, and the yellow last to remain obvious, even before white; and it is this phenomenon that has been called in to play its part, in rendering this fish an obscure object. It may be noted that all Scorpaenidae seem to be adepts at concealing coloration, but as most of them live in shallow water this is the only member with a uniform colour. The above explanation of the brilliant red colour is more likely to be correct than the theory that this fish frequents areas where red coral is present. To show to what depths Sebastes may live it is on record that it has been found in numbers dead on the surface, with viscera evacuated from mouth and belly, which is supposed to be the result of being whirled up from great depths by one of the submarine whirlpools known to exist in the Arctic seas. This is not the only service to knowledge that has been given by whirlpools; the Straits of Messina have raised to the surface the larval stages of eels in the form of Leptocephali and no doubt other examples could be given. Sebastes is also noteworthy as being a viviparous fish, and it is said that it may have as many as a thousand embryos at one time, but still more astounding is the statement that an adult female produces eggs to the number of 1,800 to 148,000 according to the size of the container. These astronomical computations must be accepted with the acquiescence usually attributed to authoritative asseverations.

I had had an opportunity of examining the dorsal fin-spines before going to Norway and had been convinced of the presence of poison glands in the spiny rays, but had had no chance of seeing the effects of a sting from this fish. But the presence of such a gland has been conclusively proved by Pawlowsky; he describes it as similar to that found in the scorpion-fishes and weevers. In a specimen caught in the Murmansk Sea he found that the gland contained large secreting cells distended with globules that took a dark blue stain. He did not describe the disruption of the globules after their discharge from the

cell, but otherwise he pictured a condition the same as I have described in the Greater Weever. It is interesting to recall that a deep-sea fish very like the Black Scabbard fish but with jaws prolonged by gristly prows, jet-black, with huge eyes, and vicious teeth, also hails from Murmansk and has a range as far south as the coasts of Madeira; and like other fish of the abyss has a dagger-like poisonous spine near its vent. This fish has to be content with an official name *Nesiarchus masutus*.

We now propose to say a few words about another Scorpion fish, the Greenland Bullhead or Sea-scorpion; unfortunately I can give no personal observations on the surroundings in which this fish lives and its description is taken from the 'Proceedings of the Natural History Society of Dublin' (1856). But it is known to frequent waters of moderate depth and with a rocky bottom, clothed with fronds of waving seaweed, to which the word kelp is usually applied. *Cottus Greenlandicus* or Bullhead is probably only a Northern form of *Cottus Scorpius* and in America the species of *Cottus* is called sculpin; and on the Californian coasts there is another species *Scorpaena guttata;* this fish also lives in rocky ground in the midst of a rich submarine flora. Both the word sculpin and the seaweed kelp have doubtful derivations. According to Beebe the word kelp first occurred in English prose in a translation of Higden's *Polichronicon* by John Trevisa (1387) and here we find it in a paragraph 'as culpes of the see, waggeth with the water'. The fish-name Scorpion is derived from the Spanish 'escorpaena' and this is said to be the origin of 'sculpin', but how did the 'sculp' become transformed from the original 'scorp'. The explanation is simple if we call in folk etymology, and it becomes clear how easy it was for the fisherman to confuse the scorpion fish with the culp fish and arrive at sculpin. Whether my conclusions are correct or not, the fact remains that the sculpin is a dweller among 'culpes' and therefore we find a type of decoration suitable for obtaining concealment among bright-coloured seaweeds against a background of dappled light or a mosaic of pebbles. Like the other Bullheads of the

shallower waters, the Greenland *cottus* has the obliterative shading of a dark vandyke brown on its dorsal surface while the side and belly have white spots ringed with deep carmine and rich brown, the tinge towards the belly being more orange. The pectoral fins have rows of white spots which are repeated on the hinder rays of the spinous dorsal fin so as to make a continuous dazzle effect. As is usual in all the members of this family, the soft dorsal fins are striped, and to a less extent the anal fins, while the caudal fin is barred. The pectoral fins are so brilliantly shaded and barred that they 'resemble and emulate in beauty the rich colouring of the tiger-moth' (Couch). It may be difficult from this detailed description to visualize the beauty of this surprising fish, which has chosen the bays and fjords of the Greenland coast to flaunt its gay attire, where few are privileged to admire it. It has all the beauty of a butterfly, but the significance of this lavish palette has, we fear, only a purely utilitarian value, its artistry only is an accidental by-product.

The Greenland Bullhead does not spend its life in deep waters, but passes most of its days in the forests of kelp which lie in the bays of an indented coastline, and being a free swimmer roams about in a tangle of waving fronds of yellow, brown, and orange seaweed. Against this background it has been necessary to adopt the obliterative 'flight pattern' of the aerial butterfly in another medium. The problem may be put in this way: if a creature is to swim amid surroundings rich and brightly variegated, it will be less conspicuous the more bold are the samples of its environment's spots and colours that it bears on its own surface. The dappling produced by the spots of varying shape on the lower margin, either reproduces the spots of light filtering through a sylvan setting, or the mottled surface of a shingly beach. Yet another detail must be mentioned; the soft dorsal, the pelvic, and anal fins are all of a lighter shade than the spinous dorsal and are marked with vertical stripes which in the caudal fin form dark bands. The effect of these markings is to suggest the

shadows of the stems of seaweed or the stalks of Gorgonids; the soft dorsal in particular is reminiscent of the closed wing of a resting butterfly which protects the wearer by its counterfeiting the stems and stalks of its environment. It is clear then that this fish is the most complete example of concealing coloration and as it also has a poison apparatus it would appear probable that this is more for offence than defence. Many fish are probably protectively coloured for aggression, even as snakes, so that the lines of Sir Walter Scott applied to snakes may also apply to venomous fish both of tropical and other waters:—

'The deadliest snakes are those which, twined among flowers,
Blend their bright colouring with varied blossoms,
Their fierce eyes glittering like the sparkling dewdrop
In all so like what nature has so harmless,
That sportive innocence which dreads no danger
Is poisoned unawares.'

The accounts of the poison apparatus of *Cottus scorpio* are rather variable but all are agreed that the period when these fish are most dangerous is in the spawning season. The poison gland is situated at the base of the opercular spines of which there are three in number and it is the third spine counting from below upwards that has this gland most developed and is moreover the most prominent.

Chapter 9

THE PLAICE-BONE

Before introducing my readers to this important and interesting fish, it may be well to remark that it is a littoral fish and that its life history has been more accurately studied than that of any other fish by means of international systems of marking. It is not surprising that wanderers are found close to their great feeding haunts, such as the Dogger Bank, and that they are sometimes caught by longshore fishermen.

In my early days in Lowestoft sea-anglers had to cast with a long line from the beach, or content themselves with fishing from the South Pier of the harbour, which is little more than an extensive jetty, as the Claremont Pier had not then been built. The more adventurous however were wont to form parties and hire a boat and, either with or without a hired hand, fish with lines to which were attached a sinker with cross pieces of stout wire from which dangled several hooks hidden by the succulent lug-worm. The boat was anchored either in the South Roads or north of the harbour in the Corton Roads. These expeditions were sometimes boring when the fish were not biting, and at other times exciting from a sudden change of weather, a bit of a blow or an enveloping fog. Among the longshore fishermen who took out parties was Joseph Delly Fletcher, known to all lovers of FitzGerald as 'Posh'; Mr. Charles Ganz nearly ten years ago published a 'FitzGerald Medley', and there can be found a number of incidents about the love and admiration FitzGerald had for this young fisherman with whom he eventually joined in partnership as owners of a drifter-lugger, in which venture it is not surprising the author lost a considerable sum of money. I knew Posh from

'ninety-four until he died in 1915 at Oulton Workhouse, aged 75. Posh must have been a fine-looking, well-built fisherman, but it is difficult to believe that at one time FitzGerald wished to have a large portrait of him to hang alongside those of 'old Thackeray and Tennyson'. He talks of his 'nobility of character' and likens him to the great names of history. Judging from the letters in Ganz's Medley, Posh must have been a confirmed 'boozer' and his financial morals must have been of the flimsiest; but one of his characteristics was his inability to keep a pipe alight, and it is recorded that he tore up a page of the author's *Sea Words and Phrases* (a proof moreover from the printer) to light his stubborn tobacco. One day my friend Chipperfield and I went out with a longshore fisherman into the Corton Roads and as we were thinking of returning to the harbour we suddenly found a thick fog rolling in from seawards. Before we were able to get any distance back we completely lost our bearings; we had neither compass nor leadline in the boat and we rowed aimlessly into space as the foghorn on the High Light was diverted by the bank of fog. Suddenly our man shouted loudly: 'We're all right, there's Posh.' We peered into the murk and saw nothing. Then he shouted again, 'Look in the water, there he go'; and all we saw were matches, matches, and more matches. Our man then explained that Posh didn't smoke tobacco, he smoked match, and if we followed the matches we would be safe in harbour in a short time. This prophecy proved correct: so with these proofs of Posh's skill as a pilot and apologies for any of the reflections of Mr. Ganz, we say, 'Fare ye weell, bor.' And now we can speak of our catch. Among the whiting, codling, and gurnards was a plaice, and in taking out the hook I happened to notice the sharp spine which projected forwards from the lower edge of the body immediately in front of the anal fin, the rays of which point backwards. This spine has no connection with the anal fin but is fused to a curious curved bone lying at the back of the abdominal cavity and known as the abdominal rod. The projecting spine may be half an inch in

length but much larger in big fish; it is circular in section with a fairly broad base which lies in a sheath. It is a common source of injury and inflamed hands in trawler fishermen, but they do not regard it as poisonous and do not place it in the same category as Bullheads, Weevers, Dogfish, and Mackerel. There are two grooves in the supporting bone leading to the base of the tooth, but I have not been able to find any trace of a poison gland. The plaice-bone is curved and occupies a curve

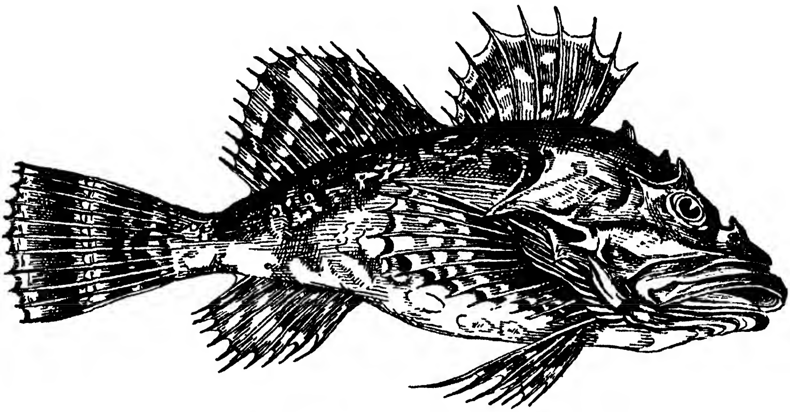


Fig. 20. Greenland Bullhead (*Cottus greenlandicus*) (After Couch)

about one third of the circumference of a five-shilling piece and therefore must give some considerable support to the spine and so perhaps may be of use in attacking its prey. This theory is supported by some observations of Cuningham recorded in his book *Marketable Marine Fishes.* After describing the almost exclusive diet of shellfish and its throat-teeth which are adapted to crushing their shells, he points out that there may often be large fleshy lumps in the stomach without any accompanying shell fragments, and he has satisfied himself that these lumps are the 'tube' fleshy feet of the Razor-shell 'Solen' and that the plaice is able to bite this off without crushing the shell. Smaller examples of Solen may however be noted in the stomach contents together with the shell frag-

ments. There can be little doubt, bearing in mind these observations, that the plaice uses its spine to spear the foot of Solen; and having prevented the shellfish from withdrawing its foot, is able to proceed to bite off lumps of its flesh at leisure. It may be asked how is it that you caught a plaice with a bait of worms; but it must not be thought that plaice refuse worms such as lug-worms, rag-worms, and tube-worms, although, as I said before, the staple diet is shellfish, especially on the Dogger. It is said that the fishermen's wives are very particular as to the site of capture of the plaice brought home by their husbands, since the flavour varies with the particular shellfish that has been its diet.

To resume the subject of this unique bone with its terminal spine so different from the anatomical connections of the spines and stings we meet in other fishes: Kyle in his *Biology of Fishes* describes the abdominal rod as being an important factor in the gradual formation of the asymmetry of the plaice, and says that as long as the gut is movable the asymmetry does not take place; but that when the rod grows forwards and the gut becomes fixed, then the eye migrates to the position in which it is found in the adult. This theory does not receive general acceptance, and I am not sufficient of an embryologist to give an opinion; nevertheless I could produce several arguments against its validity. In conclusion it is interesting to note that fishermen have long been aware of this peculiar attachment of a spine to a more or less loose piece of bone, not being formed from a fin-spine, and this is shown by their invariable reference to it as the Plaice-*bone*.

Chapter 10

MURAENA, PAINTED AND OTHER EELS

There are certain geographical areas, the names of which are all familiar but about which our ideas are the foggiest. Besides the blessed word Mesopotamia and the Ægean Sea, there is the Sargasso Sea and the Gulf Stream. The two latter are closely associated, and the interest has grown since Johannes Schmidt made his brilliant researches, which traced the European eel to its breeding ground. It might be said, with a certain amount of justification, what have eels to do with stinging fish? and it must be explained that though the common European eel (Anguilla) has no venomous spine, yet its blood has poisonous properties, so that a bite or open wound may readily become envenomed. It will be shown shortly that the Moray eel, which has always been included among stinging fish, is well known to have not only a dangerous bite but also toxic blood. We may here mention that the larval stages of the most important eels take place in the neighbourhood of the Sargasso Sea. Not only did the discoverer of America, Christopher Columbus, make his landfall at Watling Island on the easterly margin of the Bahamas, but he sailed through the Sea-weed (Portuguese 'Sargassum') whence the name Sargasso Sea. But it was not until comparatively recent times (1899) that oceanic research made an accurate study of the temperature, degree of saltness, and plankton (surface microscopic life) of the Gulf Stream, and this research was made with the object of studying the distribution of this current. James Johnstone describes how the Gulf Stream expands from March to November in a north-easterly direction,

and that in November it has reached the coasts of North Africa and Southern Europe, and at the same time there has been an expansion of the plankton-bearing water. From then until the following March the stream regains its former volume. Issuing from the Gulf of Mexico, the Stream extends out into the North Atlantic in a north-easterly direction, but curves round again to the south, forming a closed colossal eddy in the centre of which is the Sargasso Sea, a streamless region of water of high temperature. Here grows the famous weed about which romance has woven fantastic tales, but none more full of mystery than that of the birth place of the eel. This weed is a huge incubator and beneath its fronds, which spread entirely by vegetative growth, is the home of a vast fauna, which can seek protection from tropical heat and obtain an unlimited supply of plankton. But we must prick the South Sea bubble and destroy the fiction that the Gulf Stream washes our shores.

'In some way or another a drift or current of water takes origin just north of the Gulf Stream eddy, and this reaches the shores of Great Britain and Scandinavia. This drift of sub-tropical Atlantic water known as the European stream bathes not only the already-mentioned countries but also those of Iceland and the deeper parts of the Baltic and Barentz seas.'

In the Ten-pounders (*Elops*) and Lady-fishes (*Albula*) and in all the Eels (*Apodes*) the early stages, after the eggs have hatched, are elongated transparent bodies of a leaf-like shape, barely recognizable in a pailful of water, except by their mother-of-pearl eyes: this larval stage is known as 'Leptocephalus' (leaf-head) and among these larvae are individuals of all sizes, up to nearly a foot in length. Beebe relates how he took out in his hand 'a 12-inch of flexible water. There was no structure to be seen except the gleaming eyes, and yet here was a living fish.' 'When dead and preserved the body, shaped like a long, translucent, thin willow-leaf, showed delicate segments, and scarcely visible gills and stomach.' Under the microscope could be seen very long needle-like teeth. These

are the main characteristics of the larval form of eels and in the Sargasso Sea may be collected thousands of these larvae belonging to an infinite number of species, many of which are un-named as the adult forms have not yet been traced. Some are large and some quite small.

I now propose to make a few observations on the changes that have taken place in geological time in connection with the movements of continents. If you look at a map of the South Atlantic it will be apparent that it looks like a jig-saw puzzle, in which South America fits into the coast of Africa. Brazil fits nicely into the Gulf of Guinea. This is not just a flight of fancy but geological fact, and observations relating to the dispersal of animals, including fish, all point to the probability that South America has slipped off from Africa. For example catfishes that spread from India to Africa have passed on to South America and nine species are found in tropical areas which are not found in North America. If this is correct one can visualize the larva of the European eel as originally ascending eastern rivers which were then quite handy, but as the continents became separated the journey of the larva to its fresh water would gradually be extended until a journey of three thousand miles intervened. It is difficult to think geologically but this theory alone gives reasonable explanation of the migration of the European eel.

We must now give a short account of the life history of the European eel which begins with the hatching of a leptocephalus larva; this is found as a transparent leaf-like structure about 100 fathoms down and, growing rapidly, by the end of the first summer may be about twenty-five millimetres in length. They now are found in the surface waters and are carried by the European Stream to Europe, including the British Isles and Scandinavia, which they reach in about two and a half years, and then measure about three inches in length. The larva on reaching our shores stops feeding, gradually shrinks and becomes shorter and cylindrical, but is still transparent and is known as a glass eel or elver. The elvers then make for

the estuaries and rivers, which they ascend in countless thousands. In the River Severn when the season approaches the country people wait for the invasion, which is known as eel-fare, and collect them in baskets. It has been estimated that between nine and ten million elvers may be landed in one day. But still the numbers that remain are innumerable and they travel into lakes and broads and rivers, penetrating the ultimate trickle of their tributary streams. After five years of growth and heavy feeding, for the eel is a voracious animal to which nothing comes amiss, a remarkable change in its make-up begins to appear. Hitherto of a yellow or greenish colour, it ceases to feed and the body takes on a metallic sheen, the pectoral fins become black and pointed, the eyes become larger and the flesh firm and more palatable. The back, however, takes on a deep blackish tinge. We note two things: first that the change of livery coincides with the cessation of feeding, and secondly that the waste products of the food it has been gorging must be got rid of. In the chapter on pigments and poisons we note how nature made use of waste products and that iridocytes, the makers of lustre ware, store up guanin and that the chromatophores turn tyrosin into melanin so that the change from a yellow eel to a silver eel follows a simple biochemical course. This wedding garment, for such it is, has the further use of providing an obliterative shading invaluable as a protection during the long sea journey the eel is about to undertake. In the autumn, when eels are anything over five years in river residence, the urge to migrate seems suddenly to seize the silver eels. This is accompanied by a restlessness which makes itself apparent even when the eels are confined in the submerged trunk of an eel-catcher's post. In fact the eel-catcher waits for a suitable night. Such a night has been told by an old hand: 'Coarse blowy nights and good down tides we gets most of our eels. I didn't know when it was any use going arter them, till that chap put me up ter it. "Charley," says he, "if you go and stand by your trunk, if there be any eels in it, yer may soon know by the noise whether ter be a

stirry night or no with them. If the eel be a going ter move, yer will hear 'em making a noise just the same as you have heerd them when you've been a-babbing. Eels is funny things." ' 'Weird and uncanny is the noise raised in unison by the multitude of eels—a low monotonous sucking chorus as regular as the ticking of a clock';* such is the description of what you may hear when babbing. This method of fishing is with a rod and line to which a bunch of worms are tied into a ball with worsted; into this the sharp teeth of the eel get imbedded and it does not let go till it finds itself in the bottom of the boat.

The eel now makes for the sea and its migration back to its breeding ground commences. It might be assumed that the impulse was the maturation of its gonads; but the roes do not mature until the fish have entered the sea. The evidence is accumulating that the self-starter is the change that takes place in that mysterious gland the pituitary, in which definite changes have been noted previous to the migration. The tale is nearly told: the migrating fish gradually swim the Atlantic in deeper and deeper water until they find themselves back at their home, when nothing more is heard of them; but the larval leptocephalus duly appears, after being hatched out in the ancestral home, and another life cycle recommences.

The Moray Eel or Muraena

This attractive eel also belongs to the true eels (*Apodes*) but can boast no mysterious breeding journey, like the European eel, but spends its life in sea water which must be warm, and its larval form, also a leptocephalus, commences its existence in deep water, although the adult prefers the rocky shores. It is therefore not surprising to find that Muraena helena is a native of the Mediterranean Sea, and it was in this sea that I had the opportunity of examining specimens in their own waters.

The leptocephali of eels have been churned up from great

* "Norfolk Broads"—Emerson and Goodall.

depths in the Straits of Messina and these were at one time thought to be the larval stage of the fresh-water eel; but, as we have already described, this has been proved erroneous, and the larvae may be those of conger or Morays.

The Moray has long been dreaded by fishermen: Nicander speaks of the 'fear it inspires: fishermen who have captured one, throw it back into the sea because its bite is as poisonous as that of a viper'.

In the *Natural History* of Pliny details are given of the extraordinary cult of the Muraena by the Romans and the

FIG. 21. The Moray Eel or *Muraena helena* (orig.)

large sums of money that were spent on ponds for their preservation as pets and for the table. On the 'occasion of a triumphal banquet given by Julius Caesar, when he supplied six thousand of these Muraenas to the feast, he gave it to be understood that he only would be repaid by the return of an equal quantity by weight' (Couch). Lucullus expended enormous sums in forming a passage through a mountain near Naples to admit the water of the sea to his ponds; but this labour was in vain, as it is found that these eels will live in fresh water just as well as in the sea. But at least we are indebted to him for a nice biological experiment. Quoting Couch again we read that Aristophanes in his comedy of the *Frogs* reckons his Tarten-

sian Muraenae (from near Cadiz whence, according to the epicures, the best were obtained) as among the monsters, that will tear out the entrails of the wicked in hell. 'Even by respectable authority a wound by these teeth was judged a serious affair, and that eminent physician Paulus Aeginita is found prescribing equally for injury by the spine of the Fireflair Ray, the bite of the Muraena, and a wound from a Sea-scorpion—perhaps the Weever.' So wrote Jonathan Couch, and like the scientific savants of the nineteenth century poured the scorn of scepticism on the prescriptions of that devoted physician. In recent years however it has been shown that all animal poisons, from the jellyfish's to the cobra's, are due to protein bodies or toxalbumins, all readily destroyed by the same chemical means. Thus have the opinions of the learned Paul defied posterity.

The question of the nature of the bite of the Muraena, whether it was due to a definite poison gland or simply due to some salivary secretion, has led to many conflicting opinions. There can be no doubt about the bad results that follow a bite and no doubt the Roman slaves could have told how unpleasant it was to be thrown into a tank containing a number of these fish, kept for the savage pleasure of a noble aristocracy. Between Marseilles and Toulon is a small fishing port named Cassis. It lies in an amphitheatre made by the surrounding hills which enclose a small basin edged by a quay against which numbers of fishing boats are moored or drawn up on the sloping sides opposite the shipwrights' repair shops. The tall white-washed or colour-tinted houses form a gallery facing the quays, with four or five tiers of shutters, green, blue or orange, faded by the brilliant sun. Towards the harbour entrance is a larger quay for the small coasters which carry on a trade with the limestone quarries in the neighbourhood; this lies to the east and above it towers a cliff which in the afternoon glows a rich orange toned with red, separated from the limestone boulders at its base by masses of olive-grey foliage, contrasting with the deep blue of the sea. The west

jetty has a café and small restaurant and here the fishermen land their fish, and the booths of their women-folk form a background to the men repairing nets or crab-pots, sitting with outstretched legs amidst the flotsam and jetsam of a port. In the evening light a more fascinating picture can scarcely be found than the gaily coloured galleys with their high prows and canoe sterns, lying at anchor in a mosaic of gold and orange ripples in which their own brilliance is reflected. In such surroundings I spent three weeks studying the rich fauna of the western Mediterranean, and here I made my first acquaintance with the romantic Muraena. Here was the real fish, scarcely dead, as its tenacity of life is great, not crushed by passage to a large centre, nor disfigured by a sojourn in the pickle jar of a museum. Under these conditions the Muraena is the most attractive of fish. It has the usual form of an eel but its head is small and rather tapering, a thoroughbred head rather than that of a hackney. The scaleless skin is often decorated with a most artistic pattern, but may be uniformly black or brown, green or yellow, and even barred and striped. Willoughby described the colour as 'ex obscure spaditio seu fulvo nigricante et flavo seu aureo'. But this hardly does justice to the fish I had the opportunity of sketching. On a chocolate background there are a number of circular areas varying in colour from a bright yellow to a golden tinge. In an area of one and a half square inches there would be five of these patches of bright colour, some confluent and some quite discrete. In the centre of these there are a few spots of a blackish brown ranging in size from a pin's head to that of a small pearl, and these again are sometimes confluent so as to make almost heraldic designs.

This pattern is doubtless for the purpose of concealment and the obliterative scheme is similar to those patterns of snakes which serve to hide them in dead leaves and grasses. The Mediterranean Moray is fond of rocky shelters and hides in holes, but there is a background of limestone rock covered with brown and yellow seaweeds against which the coloration

we have described would cease to be obvious. It has been pointed out that Muraena is very like the conger in habits, and this similarity extends to a curious peculiarity, the tenderness of the tail: both fish are very fierce when caught and the larger ones will attack man, and the best reply is a smart blow on the tail which knocks them out; this is reminiscent of the negro who is more susceptible to a kick on the shins than a blow on the head. The sensitiveness of the tail is also seen in the conger which, when it finds itself in a boat, noses round with its tail till it recognizes the gunwale and then unless forestalled slips overboard. I cannot conclude this subject without venturing on an explanation of the vulnerability of the eel's tail. To explain this, one must go back a hundred years when a strange heart was found pulsating in its tail, beating more than twice as fast as the real heart, and quite independently. In recent years this has been shown to be the pump that drives the lymph from the superficial structures to a cistern or sinusoidal cavities into which the cells of the thyroid gland project, and the lymph together with the thyroid secretion are then carried by a vein to the heart. Thyroid secretion has a stimulating action on the heart, and, if this was suddenly cut off, a profound effect would result, akin to a knockout blow. Some of the West Indian Morays are particularly vicious, especially the green Moray, and others are remarkable for the number of teeth that so crowd the mouth that it cannot be closed. Before leaving the conger which is common around the British Isles we must recall the fact that its larval leptocephalus, *L. morrisii*, was the first to be discovered, but its significance was not recognized for many years, and it was regarded as a malformation.

The interesting problem arises why is there so wide a divergence in habits in the Moray eel and the European eel. It appears that both are primarily sea fish but that the Morays stick to the sea and do not ascend rivers, although as we have seen they can live happily in fresh water. We have seen how the European eel is a sea fish which migrates to rivers to feed;

to use Heape's expression they have an alimental migration and only return to the Caribbean Sea to spawn and die. I picture Muraena helena as originating in the Sargasso Sea, the nursery of the leptocephali, and that when South America and Africa were joined, the larva had but a short period of existence before reaching its adult form and its wanderings along the northern shore of these continents had led it into the Mediterranean Sea: the adult has been taken in the region of Madeira. Muraena finding itself in a warm sea of suitable salinity and with plenty of food saw no reason to leave its new surroundings and, as its larva could also stand the new conditions, remained an emigrant.

When we come to the question of the presence of a poison gland in connection with the teeth of Muraena we enter an arena of disputation. Naturally we look to see what Bottard has to say on the subject. He described a poison organ which he considered to consist of the palatine teeth and a secretory bag situated between the palatine and the mucous membrane. Porta more recently described sub-maxillary glands which he believed to be the origin of the venom; and finally Pawlowsky was unable to find by microscopic examination of serial sections either the glands of Bottard or those of Porta. However, he was prepared to admit that the mucous membrane itself perhaps secretes the venom. From my own observations I do not think the matter is settled beyond dispute, as on other occasions Pawlowsky's scepticism has not always led to correct conclusions. It is strange that with all the advantages and technique of modern scientific methods no naturalist living on the spot has taken the trouble satisfactorily to solve the question.

Investigation of the venom has been attempted by making macerations of the palatine teeth and surrounding mucous membrane in glycerinated salt solution. A white granular powder has been precipitated from this maceration which, when dried in a desiccator, forms flakes which can be redissolved in salt solution and tested on experimental animals. By

this method it has been established that the venom in small doses causes rapid respiration and trembling, and in larger doses clonic convulsions followed by death in ten minutes, if injected into a guinea pig. Unfortunately for the accuracy of this experiment the same results have been obtained by injecting the blood serum of Muraena into the animal. These facts, first studied by Mosso, were later elaborated in an exhaustive manner on the blood of the European eel by the same observer. Among other characters common to the bloods of Muraena and Anguilla is the haemolytic action on the blood, and in many ways the action is similar to that of the venom of a viper. With these facts before us it seems probable that the bite of Muraena derives its toxicity either from the secretions of the mouth or blood contamination. We have already noted how the Black Scabbard fish carries a poison in its mouth without the presence of any definite poison gland.

Chapter 11

SURGEON-FISHES AND TRIGGER-FISHES

In this chapter we shall consider the Surgeon-fishes and the nearly related Trigger-fishes, which abound in the seas of the West Indies and the Pacific Ocean. Hitherto we have described those species of fish with poison organs, which for the most part are individualists or solitary, and certainly are not gregarious, although some of the sharks occur in shoals, as for example the Spiny Dogfish.

The Surgeon-fish introduces us to a group of fishes quite new to us in their method of feeding, which is that of a herd browsing and grazing in large numbers on the vegetation, mostly algae, which clothe the rocks and corals in tropical seas. Their movements are placid and unhurried as they fear no evil, having acquired an immunity from any enemies by their herd instincts, combined with an ingenuity in devising a unique type of defensive weapon. We are indebted to Professor Beebe for many details of these interesting fish, which he has studied in their own surroundings by means of his original methods of diving. The Yellow-tailed Surgeon-fish (*Xesurus*) has the shape of a plaice without its distortion and swims in a vertical attitude. They vary in length from a foot to eighteen inches and may weigh from one to four pounds. Their colour is a pale slate grey for the most part, but the tail is a bright yellow and is armed at its base on either side with a row of three dermal plates, each of which supports a hooked file. On the hinder third of the body there are a number of small black tubercles or small dermal plates, the larger of which have a sharp cutting edge which develops an anterior hook. Anteriorly

there are two broad black vertical bands, one passing upwards from the base of the pectoral fin, which is separated by its own width from the other, which passes from the angle of the mouth and embraces the eye in a manner reminiscent of similar bands we have described in Poison-fishes. This rather suggests that these bands may be a warning pattern rather than a concealing device. The question of the dangerous nature of the caudal spines has been the matter of experiment by Professor Beebe, and we propose to quote the description given in his book *Arcturus Adventure* which seems to settle the matter, although further investigation is advisable.

'I took a live Xesurus and armed with thick gloves I bent its tail slightly around and rasped the sharp files against the scales of three species of fish . . . which live in the same locality as the Xesurus. In each case I had a number of other individuals of the same species, as controls, all living well in our aquariums. I watched the fish carefully, but after the excitement due to my taking them from the tank was over, I saw no symptoms of discomfort, the abrasions themselves being quite negligible. The following morning all of the four subjects of the experiment were dead, their fellows without exception being still in perfect health. There was a slight discoloration of the flesh around the wound, but no other lesions.'

I am not aware of any evidence of the presence of any specialized tissue of a glandular nature in connection with these caudal hooks, but comparative anatomy makes the existence of such tissue probable.

The coloration and the caudal armature supply material for conclusions to be reached as to the habits of this fish and the study of their teeth confirms these conclusions. These have been closely examined, but the only fact that concerns those who are not specialists is that they are admirably adapted for the purpose of scraping the algae from the surface of the coral, and point to a herbivorous function.

The slow and measured progress of a herd of these grazing fish, consisting of anything up to a thousand members, forms

a grey cloud over a cliff of coral; suddenly the leader calls a halt and by a mass intuition the whole herd stops and dives like ducks on to the weeds and with their sterns up flaunt their brilliant yellow tails in the sunlight. The coral becomes covered with a cloth of gold as the barbed banners wave in the surge, warning off any trespassers by threats of persecution. This protection obtained by a grazing herd seems to bear some resemblance to the protection given by a swarm of bees. The sting of a bee by itself is not formidable, but a swarm is fearsome. In the same way the sting of a single Yellow-tail is of little account compared with a mass attack of a shoal of stinging fish. Further we may recall that the yellow striped body of a wasp is definitely a warning coloration, and other instances might be given of the warning value of yellow, which curiously enough is the colour chosen by quarantine stations.

The Black Surgeon-fish inevitably suggests to the biologist the Black Scabbard fish by the superficial familiarity of their names and the fact they are both provided with an anal dagger in the form of a lance-shaped dart. The dart in the Scabbard fish, it will be remembered, lies between the anal fin and the vent, while in the typical 'surgeons' the spine lies on each side of the tail and when at rest is hidden in a sheath; it is however capable of being erected by the fish, which then uses it by lashing the tail from side to side. However, this is not the universal position of the lancet-shaped spine, as in the Black-barred Surgeon-fish (*Teuthis triostegus*) it lies anterior to the vent, its point reaching nearly to the anal fin. I am not aware of any experiments that may have been made as to the venomous nature of this spine, although it has an evil reputation; nevertheless its position and character are so similar to that of the Black Scabbard, which is known to be venomous, that there can be little doubt of its dangerous nature. These fish haunt the same rocky and coral shores as the Yellow-tails and also feed in packs. They are more restless than their cousins and show more fear of predatory foes, although their weapons of defence seem to be more formidable. Their dusky

colour is relieved by five black vertical bands, the most anterior of which passes up so as to be interrupted by the eye. When we consider that these fish hunt in packs, it is a little difficult to explain the value of these stripes as a protective device. But it is possible that when feeding, as these herbivorous fish do on a coralline formation such as the 'organ' coral, the massing of a number of vertical shadows might become of use as an obliterative scheme.

The Trigger-fish require a short paragraph as they possess several features suggesting that they should be included among stinging fish. They are tropical fish and near relations to the Surgeon-fish. Their armament is however an adaptation of the spinous dorsal fin. In one species (*Monacanthus*) this spine is single with a posterior groove which may be the site of specialized epithelium. Balistes, the true Trigger-fish, has as its name suggests a locking device for the spines of its dorsal fin. The first spine, which is the longest, receives the second in a posterior groove and when erected these spines cannot be depressed one without the other. The anterior margin of the first is also roughened. This locking apparatus suggests a similarity to that we shall see in the Siluroids or Catfishes.

Chapter 12

AN AFRICAN CATFISH

Before entering on the subject of this very specialized fish, we must make a few very general remarks about Catfish or Siluroids. Their distribution is at first sight difficult to explain. Their main habitat is Africa and the northern part of South America, which is attributed to the former junction of these two land masses in Cretaceous times. The presence of the Mad Toms and Stone Cats in North America is explained by the fact that they came from the North and are of Palaearctic origin, as fossil types dating from the Eocene have been found very similar to the existing species of Catfish. The pectoral fins have simple or branched rays and there is usually a stout spine, often serrated, which may also have a locking mechanism for fixing the spine. The strong first dorsal spine is often serrated on one or both of its edges, capable of inflicting a nasty wound; sometimes this spine is attached to the body by means of an elaborate ball-and-socket joint. Many Siluroids have a poison gland in the angle between the pectoral fin and the body, known as the axillary gland (axil meaning angle) which lies close to the base of the spine. The anterior spine of the dorsal fin also has a poison gland. The axillary glands open by a pore and the glands themselves are of the nature of a composite skin gland, a modification of such glands as secrete sweat or sebum in higher vertebrates. They are pear-shaped and divided into three main lobes which are further subdivided; the cells are very like those of the granular gland of the Salamander and there is a pigmented capillary layer as we have described in the glands of the Sting-ray and the Spiny Dogfish. The pain produced by a sting from the Mad Tom or Stone Cat has been described as like that of a hornet.

The biologist who describes a species of fish without any first-hand knowledge enters on his task with some misgiving, but I approach the subject of an African Catfish without this disability, having been provided with several specimens of the 'upside-down fish' of the Nile by Mr. J. R. Norman. The reason of this gift will appear when I have given a short account of this fish, *Synodontis batensoda*. Many of the species of Synodontis which live in the Nile and other African rivers are in the habit of living at the surface of the water in an inverted position, with the belly upwards. Associated with this

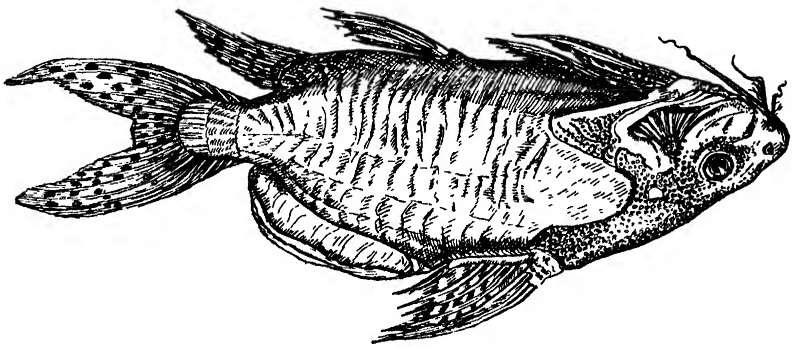


FIG. 22. The 'Upside-down Fish' of the Nile (*Synodontis batensoda*)

reversed position the normally ventral surface has become dark brown and the dorsal light silvery grey. This peculiar habit had been noticed by the ancient Egyptians who have repeatedly depicted this fish in its anomalous position. The relation of the incidence of light to the distribution of pigment in the skin has been already noticed in discussing obliterative shading in other fish, and the reversal of the normal pigmentation in Synodontis is no doubt the result of a protective adaptation. This fish, as the drawing shows, has the usual barbels of the Family, a strong dorsal spine, and a serrated pectoral with a locking apparatus. Bony scutes pass back from the head to the commencement of the dorsal fin. The anal and caudal fins are marked with black spots; there is an adipose

fin which in *Synodontis batensoda* extends from the dorsal to the caudal fin: it is thick at the base and is fringed by a thin membranous margin. When one looks at the fish swimming in its position of adoption, one notes the striking resemblance it has to the lines of a modern racing yacht: a bold curve passing from the bow backwards and downwards is continued by the adipose fin, which lies in the position of the lead keel of such a craft, and it seems that this fin has been further adapted to facilitate swimming in this new position. It has been suggested that the upside-down position, being found so often in dead or dying fish, may be an imitation of death, and adopted to deceive its enemies. This is a pure speculation and no evidence has been produced to give rise to any justifiable credence. With the absence of any other explanation, it occurred to Mr. Norman to ask me to make a series of investigations on the brain of these fish. This introduces us to a branch of the study of fish, of which I have been one of the earlier workers, and so it requires a little preliminary explanation. It has been established that functions are reflected in the pattern of a fish's brain and that, even in members of the same family, different pictures are provoked in the brain's structure according to the habits and habitat of a fish. In this way much can be learned, as a few examples will show.

The most simple case, that can be seen in any of our rivers, is that of the carp and the gudgeon. The carp is a mud and weed feeder and has a special palatal organ which enables it to sift the nutriment from inorganic matter, and has the hinder lateral areas of the hind-brain very much enlarged, while the gudgeon gropes and grubs with its barbels and has the central lobe of the hind brain distinctly large; the first is enervated through the vagal nerve or tenth, and the second through the facial or seventh. The mid-brain or cerebellum is continuous with the hind-brain by lateral swellings known as the acoustico-lateral lobes and the varied functions of this united area are not clearly defined. These are the function of equilibrium, that of audition, and that of receiving the impulses from what

is known as the lateral line. In a carp the area that is supposed to represent hearing and called the central acoustic area is small, while fish like the bleak and the Engraulicypris, that live on the surface and are plankton feeders, have a large central acoustic area. As regards the equilibrium we find marked differences between the acoustico-lateral lobes according to whether they are in fish frequenting moderate depths, or abyssal fish.

With these few explanatory remarks we can now return to our investigation. My first study was the examination by serial sections of the brain of *Synodontis frontosus*, a fish which has a normal attitude towards life. I then made naked eye drawings of the brain of *S. batensoda* and also microscopic drawings of serial sections and compared them with those of a normal fish. Three studies were made, an adult and a young specimen from the Nile, and a small specimen from the mouth of the Gurara, a tributary of the Niger. Detailed drawings of my results can be seen in the *Proceedings of the Zoological Society of London* (part 2, 1934). In all the sections we noticed marked asymmetry in the acoustico-lateral area, the right side being considerably the larger, and it produces a more prominent bulge or protuberance laterally. It also extends to a greater extent dorsally. The asymmetry was more marked in the adult specimen than in the young examples and, as far as I know, these results have not been disputed; but on the other hand I have not seen any confirmation of this very remarkable condition. It seems, however, that these observations deserve to be mentioned, as they may be of interest to travellers in Egypt in happier times.

I may be permitted to mention that a simple account of the relation of function to brain pattern can be read in my book *Body and Brain of Fish* (The Technical Press).

We cannot leave the subject of Catfish without mentioning some of the more poisonous Catfish of the tropical parts of South America. There is a Catfish in Southern Florida and in West Indian waters which has a poison gland particularly

virulent. Fishermen regard it with great fear and look upon wounds as particularly dangerous. Convulsions sometimes occur and the opinion is widespread that lockjaw may result from these injuries. This however is probably a fallacy, as primitive people cannot be expected to realize the difference

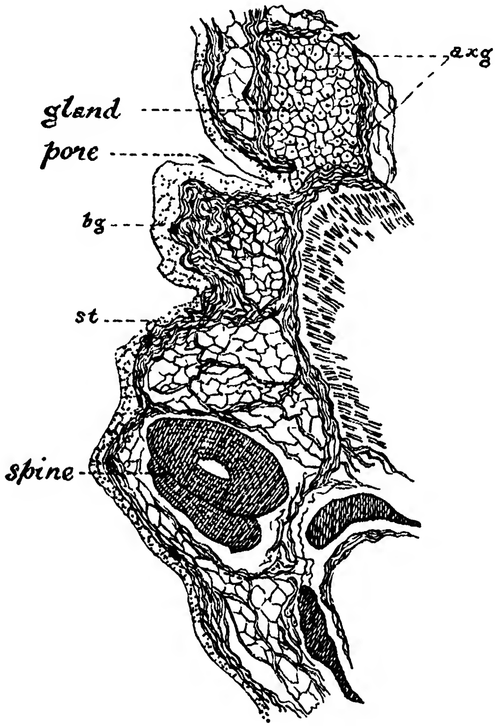


FIG. 23. *Plotosus anguillaris* to show axillary gland and pore and spine (After Pawlowsky)

between tetanic spasms and the specific infection of tetanus. According to Rusby a similar species is distributed widely in the South American streams and is known as the 'mata cayman' (alligator killer). 'So dangerous are the poisonous fin-spines that they are said to be poisonous to alligators who swallow them. On a number of occasions when I have taken these fishes in the Orinoco, Magdalena and Amazon rivers, I

have been warned by the natives against exposing myself to wounds made by their pectoral spines.' This author must be again quoted: this is what he says about the 'tigre': 'We have already mentioned the large catfish known to the natives as "tigre" but this is by no means the largest of the many species

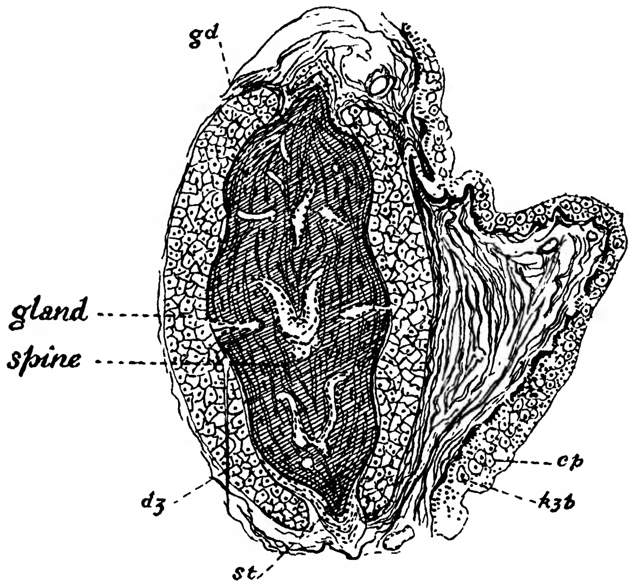


FIG. 24. *Plotosus anguillaris.* Section of spine of pectoral fin in the middle third to show glandular tissue (After Pawlowsky)

of catfish which frequent the River Beni and other similar streams in the same region. The Quassia, known by many different names, is of enormous breadth and stoutness as compared with its length, the head forming a disproportionate section of the entire weight: its mouth is broad and its jaws very strong. At the back of its dorsal fin is a large imbedded gland which secretes a liquid of intensely disagreeable odour reminding one slightly of musk and a little of skunk. When this fish is caught for food the gland is immediately removed to prevent the flesh being permeated with its flavour.'

The function of this gland is a matter of conjecture; as far as one can ascertain, there is no evidence to support the conclusion that it has venomous properties. It would appear probable that it would alarm a predatory animal.

Some Catfishes inhabit estuaries and some frequent the shores in tropical regions. Catfishes of the family Plotosidae are known to be particularly dangerous. According to Gimlette, *Paraplotusus anbilabris* is the most dangerous of the Catfishes in Malayan waters, and is much dreaded by the Malay fishermen on account of the severity of the wounds, produced by the serrated spines both dorsal and pectoral. Some compare its sting with that of Synanceia. It is common in the sea and estuaries of Penang. This fish cannot eject its venom until the barbed spine is broken, because the poison apparatus is entirely closed. When the fin is erected the skin is stretched and the spine bursts through. In this respect it is similar to the Satan fish of Java. *Plotosus anguillaris*, as its name suggests, is an eel-like fish with at least eight long bristle-barbels which project straight out from around its mouth like an exaggerated stiff and ugly moustache. It occurs in the rivers, estuaries and seas throughout the Indo-Pacific region. The pain of the sting has been likened to that of a hornet so we see how widely this symptom of acute pain has been noted in venomous fish. The poison of Plotosus anguillaris has been investigated by a Japanese observer, Kabeshina, who examined the contents of small cystic distensions of glands at the base of the spines; he found two active principles—a spasmin and a haemolysin—which very soon lose their toxicity and are very readily destroyed. There can be little doubt that the nerve and blood poisons of the weever are of a similar nature.

The spines of Plotosus were first described by Bottard but Pawlowsky has pointed out certain details which do not agree with Bottard's conclusions; the true anatomy of the axillary gland is figured and described in his monograph.

Chapter 13

MALAYAN VENOMOUS FISH

When the *Beagle* with Charles Darwin on board left Australia and sailed for Keeling or Cocos Islands, which are about six hundred miles from Sumatra, he passed an area known as Wallace's Line, some distance away. Between Borneo and Celebes is a great zoological gulf fixed, and this imaginary line, called after the great naturalist Wallace, is remarkably illustrated by comparing the fauna of these islands, especially the true fresh-water fishes. In the Indo-pacific region there are two regions that interest us in connection with the distribution of fish with poison organs: an Australian region including Australia, New Guinea, and all the islands of the Indo-Australian archipelago, lying east of a line running between Borneo and Celebes, and an Indian region including India, south-eastern Asia, and the islands of Java, Sumatra and Borneo. To quote Norman: 'Wallace's Line probably represents the original line of separation, when Australia was severed from the Asiatic continent.' This ancient separation explains the almost complete absence of true fresh-water fishes in the Australian region, so that the only fish with poison organs in Australia are sting-rays, a shark (the Port Jackson shark) and two sea-going Siluroids, *Plotosus* and *Arius*, while Borneo and the Malay peninsula have hundreds of species of Carps, Catfishes, Loaches, and fish with accessory breathing organs for terrestrial excursions. A very common Catfish in Borneo known to the natives as 'ikan baong' is a scavenger, but gives a lot of sport to both natives and the officials of the islands. Its poisoned pectoral spines are rightly feared, but the methods of catching these bearded animals are interesting to those who are inclined to doubt the hearing

powers of fish. If when bottom-fishing with worms the fish fail to bite, the native fisherman puts the closed fist into the water and, suddenly opening the hand, produces a squeaking noise; this is quite sufficient to attract the fish, and, oddly enough, as they are hooked and pulled to the surface they also emit a peculiar sound. The hearing is no doubt aided by the presence of a swim-bladder, connected by a small chain of ossicles (Weberian ossicles) with the internal ear, which is characteristic of this family of fishes, and may be regarded as an aid to hearing.

We may now leave Borneo and cross over to the Malay Peninsula, where the presence of fish with poison organs is so marked that, in a book on *Malay Poisons and Charm Cures* by Dr. Gimlette, there is a whole chapter devoted to poisons obtained by Malays from fish.

Through the kindness of many friends who have lived their lives in the Malay Peninsula, I am able to speak with first-hand knowledge of the venomous fish of this region. The most important contribution that the Malay States have given to this branch of biology is the final and decisive evidence it has provided as to the function of the lateral flaps of the groove of the spine of Trygon that I had assumed was to protect the glandular epithelium of the triangle; the glandular tissue had hitherto only been suggested by the presence of scattered groups of cells in this area. I had many years previously observed, in sections of the caudal spine of *Trygon pastinaca*, lateral processes ending in a small skein of pigmented blood-vessels, enclosing a triangular area, which seemed to be continuous with the glandular area filled with secreting cells at the base of the spine. I recognized that these processes were in reality sections of lateral flaps which would act as shutters to protect any soft tissues that were enclosed in the lateral grooves. Now, at long last, I was to obtain sections in which the manipulation of preparation had not impaired the completeness of the sections, and in which the friable glandular tissue had not been displaced from its site in the groove. The drawing which I reproduce is

a section drawn from under high power magnification and shows all the details of this unique mechanism. Here is to be seen the lateral groove at the tip of the spine, in which an epithelial structure lies similar to the epithelial triangle at the base of the spine. The gland is covered in by superficial lateral flaps and, issuing from the gap where they approach each other, globules of secretion are seen in the process of being discharged. The function of the flaps is not only to serve as a protection to the epithelium but the pigmented capillaries, that I have already mentioned, serve to supply the melanin products, the precursors of the active secretion of the cells.

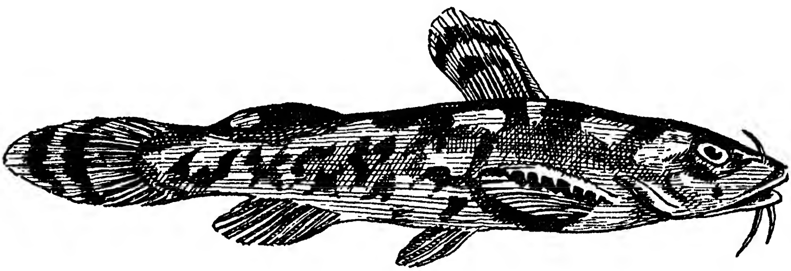


FIG. 25. *Schilbcodes furiosus* (After M. Phisalix)

As we all know from the accounts of recent campaigning in the neighbourhood of Singapore, mud and 'padi' swamps, ditches, drains, and sluggish rivers make the wet season a veritable nightmare to troops, but are a happy hunting ground for mud-loving fish. The fish that interest us are all members of the large family of Siluroids, a family almost as large as the Carps. It will be interesting here to mention the connection of the Asiatic Catfishes or Siluroids with the North American Catfish of which the Stone Cats and Mad Toms (*Noturus* and *Schilbeodes*) are widely known. The presence of these fish in North America is explained by the discovery of the geological representation of several species in tertiary formations, and the finding of similar fossil species of the same type in the tertiary formations of Sumatra; this seems to indicate a very early

connection of the two continents by a northern bridge. We give a drawing of *Schilbeodes furiosus* (after Marie Phisalix) to show the serrated pectoral spine. Both this and the dorsal spine are venomous. An axillary gland opens by a pore near the base of the pectoral fin, and the secretion from this pear-shaped gland anoints the barbed spine when it is abducted. Reed has shown that its secretion is poisonous.

The 'ikan keli', *Clarias batrachus*, is, as its name implies, a toad-like fish, and like many other Siluroids is of repulsive appearance. The natives mix its gall and cutaneous slime with opium and Indian hemp, and therefore the poisonous nature of the various components cannot be accurately estimated. Poisoned wounds are inflicted by its pectoral spines, which are attributed by some to its mucus, but the existence of definite poison glands is now so well established, that it is more probable that the slime is not the villain of the piece. An interesting remedy for the poison, according to the natives, is the application of the brain of the fish to the poisoned wound and rubbing it in; this, as my old teacher Sir Thomas Barlow used to say, 'is not foolish', as it is known that brain tissue combines with toxic bodies and that combinations of cobra venom with a fatty substance called lecithin also take place. This fish is also said to mew like a cat when caught, and this is the more likely when we recall the experience already noted in Borneo. Other fish with barbels mew, for instance a Phycis (a Forkbeard) I examined in Madeira, with lovely whiskers, certainly imitated a cat, and in this case the noise was no doubt due to the shape of the swim-bladder, which had two constrictions and two red muscular areas at the anterior attachment which were capable of expelling air through the anterior constriction. But a more dangerous fish is another Siluroid called by the natives 'ikan sĕmbĭlang' and by scientists *Paraplotosus albilabris*, and another species with a more virulent venom, *Plotosus anguillaris*, which occur in the estuaries and seas in this region. This is the only fresh-water fish of this family that has returned to the sea, and has reached

Australia by sea and again resumed a fresh-water habitat. Perhaps this is not the only fresh-water fish that has had such various experiences, as emigration is the only explanation of the family of Ariidae in Australian rivers. It is very strange that with all the local experiences of native fishermen, which have been recorded by naturalists throughout the ages, such eminent names as Sonnini, Lacépède and Cuvier (1769–1832) should still be numbered among the sceptics; as I have written elsewhere, Lacépède on every possible occasion denies the existence in the Sting-Ray, Weever, Scorpaena, Plotosus, and Muraena of any poison organ and just as energetically Cuvier supports him, but allows that the prick of certain fish is dangerous and causes acute pain.

We will now describe more fully the characteristics of the Plotosidae.

Plotosus anguillaris is, as its name indicates, an elongated eel-like fish with dorsal and anal fins extended, so as to make an almost continuous fin of the same length as the vertebral column. In front of the dorsal fin is a sharp spine of evil content, and even more dangerous is the pectoral spine, while in the axilla, near the root of this spine, is an opening which leads into a poison gland similar to those we have already described in North American catfish. But this fish is remarkable for the number of its barbels, eight in number, two of which are situated just in front of the posterior nostril. Two white longitudinal bands distinguish it from other species. The well-known Russian authority, E. N. Pawlowsky, in pre-Soviet days held a post in the school of Zoology in the Kais. Militarartzlichen Akademie zu St. Petersburg, and when he visited London I had a meeting with him at the School of Tropical Medicine, where we exchanged views on the subject of poison glands in fish and I was able to convince him on the subject of Sting-ray. But I mention the incident here as he presented me with a copy of his work on Plotosus and other fishes; the drawings of the pectoral spines of this fish are particularly clear and convincing, and I have had them re-drawn for inser-

tion in this book. But apart from the anatomical aspect, we have both direct and experimental evidence of the venomous nature of this fish. The pain is described as like the sting of a hornet; Calmette quotes I. Kabeshima, who has described small cystic distensions of glands at the base of the pectoral spines; he found two active principles, a 'spasmin' and a 'haemolysin', in general language a substance causing spasm and another which causes dissolution of the red corpuscles just as we have described in Weever venom: this provides another link in the chain of reliable observations that establish the existence of definite poison-organs in certain fishes.

We have already mentioned *Clarias batrachus* as a toad-like fish and this seems a suitable opportunity to mention the family of Batrachidae or Poison Toad-fishes which are provided with such a perfect poison apparatus that it might be thought that snakes and especially vipers had used it as a model for their venomous fangs.

The Poison Toad-Fish

Poison Toad-fishes are small tropical fishes that live near the bottom, and are best known from one or two species that inhabit the coasts of the Atlantic and Pacific oceans, near the isthmus of Panama. They were first described by Günther, and as I have had no opportunity of examining a specimen, we must be content with the description given by him, which seems to describe a fish remarkably similar to the lesser weever. Günther says that 'the most perfect poison-organs hitherto discovered in fishes are those of "Thalassophryne", a Batrachoid genus of fishes. In these fishes the gill-cover and the two first dorsal spines are the weapons. The opercular spine is long, narrow and freely movable'; and instead of being merely grooved as in the weever is hollow like the venom-fang of a viper, perforated at its base and its tip, and is further connected at its base with a sac capable of secreting venom, which is discharged through the canalized spine. A similar mechanism is found in the two perforated dorsal

spines. The head is broad and flattened and the mouth is almost vertical, while the eyes gaze upwards as in the Star-gazer. The scientists have put this fish in a family called Batrachidae (*Batrachus*, Gk., toad), the same word Batrachian being used for frogs and toads; the name has been given to the fish on account of some fancied resemblance to a toad, but if its poison gland is taken into consideration, it would have been more suitable if it were likened to the vipers, which, among venomous snakes, are typical of the species having perforated fangs. There is probably a fallacy in the minds of the givers of names in suggesting the resemblance to a toad, because it has long been a pet theory of ichthyologists that the slime of fish is venomous, especially those that have defensive fin-spines; as the slime of many toads and some frogs has two kinds of venomous secretion, provided by their skin glands, it would seem natural to associate the dangerous wounds produced by the spines of the toad-fish to a cutaneous secretion. There is, however, little doubt that all fish which are able to give envenomed wounds are provided with a specialized poison apparatus.

The close association of the teeth, even of the higher mammals, with the scales of fish, is a very interesting and revealing subject, and deserves an explanation, as it bears on the subject of poison-spines and fangs. The more primitive fish, sharks and rays, have the earliest type of scale. Their surface is usually rough and prickly, due to what are known as dermal denticles, each of which consists of a bony base imbedded in the skin and a projecting spine of enamel, which results in the formation of shagreen. The base is hollowed to form a pulp cavity and consists of dentine.

As Professor Poulton once wrote: 'Few people I suppose, realize that their teeth are among the most ancient of the parts that make up the human body'; and, we might add, the body of all the higher vertebrates. If a section of the lower jaw of an embryo or early baby dogfish is examined, it is possible to recognize the spiny scales or dermal denticles on

the outer surface of the jaw; the outer skin is seen to pass over the edges into the cavity of the mouth, carrying with it denticles which are in a transition stage; this, however, is not obvious until the lips are formed when the denticles in the region of the jaws enlarge and gradually assume the form of teeth, while those on the outside remain unchanged. To put it shortly, teeth are directly descended from some ancestral form that was covered with scales, like a shark's denticle, which migrated over the lips into the mouth, and, without any essential modification of internal structure, became adapted to act as teeth. The scales and teeth of sharks are, like our own teeth, made up of a hard substance called dentine, with an internal pulp cavity and an outer layer of a still harder nature called enamel. Thus the teeth of all fishes have a strange history, being merely a local modification of the bony prickles that form the surface armour of early fishes, called Selachians or cartilaginous fishes.

Let us now consider the development of the poisonous spines of fish, and we turn at once to a species of cartilaginous fish with a poison organ, namely the Spiny Dogfish or Spur-dog. A cross-section of one of the spines that project above the anterior margin of a dorsal fin shows a central cavity enclosed by dentine and this again on its anterior surface has a layer of enamel, while the posterior surface is slightly concave and lodges a special tissue which secretes its venom. It is evident from this description that this fin-spine is nothing more than a modified dermal denticle. A comparison of this formidable weapon with the fang of a poisonous snake shows a great similarity, as in many snakes the fang is grooved and not channelled. However, in the Poison Toad-fish we find a hollow spine with a poison sac at its base which is comparable to the newfangled perforated spine or tooth of a viper. It would be more correct to say that the poisoned spine of a fish was the precursor of the hollow fang of a snake than to say that the Toad-fish had reached the same perfection of apparatus as the highly specialized viper.

Chapter 14

CHIMAERAS

Before describing the poisonous relatives of the sharks which infest the North Atlantic coasts of Labrador, I must relate how I first became interested in the diseases and accidents of the fishermen of Newfoundland. Dr. Grenfell, recently knighted for his life's work in the interests of these fishermen, many years ago inquired of the Director of the Institute of Medical Research in London (Mount Vernon) whether he could advise him on the treatment and cause of 'water-boils', which caused a lot of suffering and disability among the cod and halibut fishermen. The matter was referred to me, as I had already shown by my writings some knowledge of diseases peculiar to fishermen. I was able to point out that these boils, which spread up the arms which had been excoriated by 'oilies' soaked in frozen water, were due to an infection with a common pus-producing micro-organism (*Micrococcus pyogenes aureus*), which, I suggest, might be termed shortly 'the golden fester-bug': I had grown this fester-bug and obtained pure cultures which did not show any specific difference from that of the ordinary boil and suggested that therefore the treatment was the same. I never heard whether my suggestions as to treatment were successfully carried out, but I did not tell Dr. Grenfell what I learnt later from an observant Lowestoft fisherman. I happened to ask him why do we see so few cases of water-boils nowadays? 'Oh,' he replied, 'because we don't use each others' towels now, and we each has his own soap, so that when one of us chaps gets a water-boil it isn't handed all round the ship; in old days once one of us started we all got it.' I think his advice was more valuable than all my pseudo-science.

Having thus got interested in the Newfoundland fishermen, I was soon to learn of the serious effects of the spines of the back-fin of a fish common in the deep waters off the banks to the north of Georges Bank. This is known as *Chimaera affinis*, a fish akin to the sharks, which is caught by the halibut fishermen sailing from Gloucester; it is said to be caught at depths of 200 to 1,200 fathoms, and its habitat is the Canadian side of the North Atlantic. This fish is reputed to be poisonous, but no writer, as far as my reading informed me, had found or investigated a poison organ in connection with the very formidable spine which is characteristic of all Chimaeras. I was, however, able to get specimens of a closely allied species, *Chimaera monstrosa*, which I will now describe.

The Chimaeras are queer fish. Their nearest relatives are the sharks which they resemble in their cartilaginous framework and also in their connubial peculiarities, being in the possession of claspers. But they have a vestige of an operculum, and other important differences which need not detain us here. The name chimaera in mythology is applied to a composite monster with the tail of a dragon, the body of a goat and the head of a lion. The old writers on ichthyology were more inclined to mythical abstractions than comic comparisons. A comic attitude to the strange appearance of this fish is given in the following lines from a child's book of comic animals:—

My name is Chimaera monstrosa
My body gets grosser and grosser
From the tip of my tail
Which is merely a flail
To my head with the face of a grocer.

The tapering body ending in a whip-like tail with a head like a human cartoon, and a large spine in front of the dorsal fin, which is often cowl-like in appearance, completes an outline of this strange fish. But the two points that we propose to consider are the ancestry of this fish and its coat-of-arms. The latter will be discussed first, as it is only by a detailed study of

the spine on its dorsal surface that we can trace its geological relations. I was led to a study of these spines by the impetus given to my hunt for poisoned spines by my discovery of poison glands in the Spurdog and the Port Jackson Shark. Through the kindness of Dr. Russell of the Ministry of Agriculture and Professor Goodrich of the University of Oxford I have been able to examine two specimens of *Chimaera monstrosa*, one from the Lousy Bank in the North Sea and the other from the Mediterranean Sea near Messina. The dorsal spine is a formidable one and has a special attachment to a vertebra

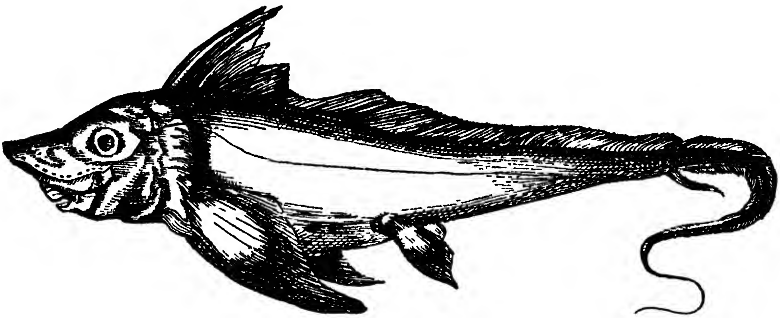


FIG. 26. *Chimaera monstrosa*

(neural apophysis) by a joint that allows it to close with the dorsal fin, and lie in a deep groove in the back. The spine is hollow and made of cartilage with an outer layer of dentine. A cross section shows it to be oval, with the long diameter median, and the posterior end cut off and grooved where it faces the anterior margin of the dorsal fin. The anterior margin of the spine has a keel which may be smooth as in *C. monstrosa* or armed with small teeth as in the Pacific genus. As the poison organ in this fish has reached the culminating point of development in cartilaginous fishes, it needs further description. The details revealed by the examination of sections I will describe as simply as possible. The margins of the posterior groove are armed with a row of denticles, and these abut against a groove on either side in the adjacent margin of

the dorsal fin, which contains a specialized secreting tissue; and when the spine is closed down, the denticles, which are also surrounded by epithelium with follicles, fit into the grooves of the fin. These can be seen by the naked eye to be filled with a glistening white band very similar to that we saw in the spine of the Spurdog. To sum up this ingenious contrivance, there is a strong spine armed on its hinder margin with two rows of teeth which when closed lie in a bed of venomous tissue and when elevated to attack rise with poisoned barbs. In this way the entry of the spine into the victim does not damage the poison gland, lying in the grooves of the fin, which remains ready to anoint the barbs afresh. The envenomed nature of wounds from Chimaera has been described and the wounds inflicted are very much feared by the Spanish fishermen. Death sometimes occurs after a severe wound.

In Zittel's *Palaeontology* there is a description of the fossil spine of Myriancanthus, which closely follows the description of that of *C. monstrosa*. It dates from the Jurassic period and many specimens have been obtained from the Lower Lias of Lyme Regis. To those whose knowledge of geological periods is vague, it will be wise to say that the Jurassic immediately precedes the Cretaceous period, when our chalk cliffs were laid down, and it was in the chalk period that the Chimaeras had their day. There are very few existing Chimaeras to-day, and they are the descendants of an important group which had members of relatively enormous dimensions, compared with living species which are usually three or four feet in length. The diet of modern Chimaeras is a curious cosmopolitan collation of seaweeds, worms, crustaceans and molluscs, and even fish. This is odd as their teeth are armed with flat plates studded with hard points. We now see that the three genera of sharks with poisoned spines represent very old types, which existed in vast numbers. And my work has clothed these dead bones with living tissue and populated cretaceous seas with savages with poisoned spears. Further, we learn that the three types were pelagic, bottom feeders or general gluttons.

Chapter 15

PROBABLES AND POSSIBLES

Sawfishes (*Pristidae*)

The Sawfish Family (*Pristidae*), shark-like rays which have the snout prolonged into a long flat-toothed rostrum on the lateral margins of which the teeth are inserted, occur in all warm seas but also inhabit estuaries as in the Gulf of Mexico and ascend the Zambesi and other East African rivers as well as the larger Indian rivers.

The Sawfish may use his saw as a spade and grub and grovel about in the muddy sand of tropical waters or it may rise from its bed and ravage the shoals, like the scythed wheels of a chariot among unarmed opponents, with its projecting teeth. Its food is therefore partly of small fishes and partly of crustaceans and other creepers of the silt. The general appearance of a Sawfish is that of a ray with shark-like characteristics. It is only a little flattened and its pectoral fins are not spread into a continuous lateral extension and it has a caudal fin of some power. Therefore it propels itself by its tail and not by undulatory motions of its fin margins. The dorsal fins are large and sharp and shark-like in position. Norman sums up this ray-like shark by saying 'in all essential characters however it is a true ray and has clearly been derived from ancestral Guitar fishes'. Most people are familiar with the saw or rostrum, and have been offered it in curiosity shops or gazed at it from a distance with childish wonder and 'curtiosity'. In a fishing or seaport town where many of its inhabitants 'go foreign', these saws are to be seen decorating the walls of the front parlour, and, owing to this very laudable habit of collecting, I have seen and handled a number of specimens. We have seen how the sting-ray has a toothed spine at its stern but the Sawfish has

chosen its bow or prow for its toothed rostrum and just as I have been able to demonstrate a poison gland in the sting-ray I propose to suggest the possibility of a venomous epithelium in the teeth of the saw. These have been recognized as much enlarged dermal denticles implanted in deep sockets and I have observed that in certain saws, belonging to a species that I have been unable to identify, the teeth are peculiarly modified; the posterior margin of each tooth instead of being sharp is distinctly grooved, which reminds one of the condition found in the dorsal spine of the Dogfish (*Squalus*). Moreover, this groove is occupied with some dark brownish substance which in a dried specimen strongly suggests the desiccated remains of some soft tissue, probably of a glandular nature. The nature of these grooved teeth seems to justify the inclusion of Sawfish among the 'probables' and, if this suggestion can be confirmed, there would be another addition to the list of poisonous fishes, which doubtless will in future be very much enlarged.

Percidae

The river Perch (*Perca fluviatilis*), which is well known in the fresh waters of the British Isles, is a prickly fish which has harsh scales and is remarkable for its black bands and reddish fins. These bands are vertical, and three usually extend up and on to the first dorsal fin which is spinous, and thus tend to obscure the fish when hidden in the reeds. It is also noted for the diminution of the intensity of the colour bands under the influence of emotions, as fear. The spines of the dorsal fin are said by Bottard to have a groove on the posterior aspect, and he has observed small glandular masses at their base and also in connection with the opercular spine. The second dorsal has soft rays. Most fishermen avoid a sting from the dorsal spines, as the wounds are painful and readily become septic. The behaviour of this fish has been studied and it has been noted that if alarmed when lying at rest on the bottom, its first reaction is to raise the rays of the second soft back fin, while the spinous is not erected till the alarm is so great as to make it

swim away. This surely suggests that the dorsal spines are not protective in function and are only erected when the fish is ready to attack. The time of year and the environment would seem to influence the development of the glandular tissue which is possibly the source of a poisonous secretion.

Chapter 16

THE RAYS AND THE HARPOON

In September 1931 I was down on the Fish Market at Lowestoft during the early morning in quest of a specimen of a Skate (*Raia*), as I was anxious to see for myself the electric organ which has been described in this fish. I had recently completed a paper on the Electric eel for the Zoological Society and as there was little chance of obtaining a specimen of the electric ray, Torpedo, seldom seen on the east coast, there was no other choice if I wished to continue my study of electric fish.

The electric organ of the Skate is small and rudimentary, and instead of being situated, as in Torpedo, near the head and between this and the gills, each organ lies on either side of the terminal portion of the tail. The details of this organ have been worked out, and in general principle they do not differ from those described as existing in the Torpedo and the Electric eel, and as the shock they give is slight, few people are aware of its existence. A good picture of a section of the gland can be seen in Bayliss's *General Physiology*, reproduced from an article by Burdon-Sanderson and Gotch in the *Journal of Physiology*, and a further very instructive drawing has been published by Cossar-Ewart, which shows the gradual transformation of a muscle fibre into an electric plate. As I looked round I was approached by Mr. Hall, a trawler owner, who asked me to come into his office, and there he unlocked his safe and produced a harpoon-head, made of stag's-horn, that had been retrieved from a mass of moorlog trawled up by one of his skippers from the north of the Lemon and Ower sands. Moorlog is submerged peat, which exists in large logs in those parts of the North Sea which had once been a land surface join-

ing Britain to the Continent; it is a great nuisance to the trawlers as it gets into the trawl, and damages the net. The Lemon and Owers banks are parallel sands that run north and south for about twelve miles outside the Haisborough Sand. Lemon has nothing to do with Lemon sole nor with 'limande', the French for flat-fish; but in the Lansdowne MSS attributed to Clement Paston (fifteenth century) we read 'and if ye sail from the Spurne—and if it be in the night ye shall go but XVIII fadome from the coste till ye gesse that ye be past the Limber and Urry'. Now Limber has an alternative form Lymnar (1500) meaning the shafts of a vehicle, and the French have 'Limonière' from Limon a shaft, for our word limber. As these two sands are like the shafts of a vehicle, it is most probable that Limber has been replaced by Lemon; such are the vagaries of etymology. However, Owers is a common sand-name and we find it in the Owers off Selsea Bill and means either a shore or the bank of a river. The root is Or or Ora and is found in Windsor, and there is a village in Dorset, Ower, which appears in Domesday Book as 'Ora'. Realizing the importance of this find, I arranged an interview with the skipper of the *Colinda*, an intelligent fisherman named Lockwood, and wrote down a verbatim tale of his discovery. 'We were fishing halfway between the two north buoys in mid channel between Lemon and Ore (note the pronunciation). We hauled a bit of moorlog about four feet square and three feet deep. I heard the shovel strike something and thought it was steel. I bent down and saw something, so took it below. This object lay in the middle of black log.' Lockwood cleaned it up a bit and then locked it up in his sea-chest and on his return to port entrusted it to the owner. I purchased the harpoon-head with the proviso that I would give it to a museum; this gem, so perfect that it might have come out of a Bond Street shop, is $8\frac{1}{2}$ inches long and is oval in cross section and is carved on one margin with a series of recurved barbs, seventeen in number: the barbed portion is $6\frac{1}{4}$ inches long, and tapers to a point. The other end is blunt and for 3 inches is marked with oblique

lines which seem to show that the harpoon had been firmly lashed to a long shaft. Experts pronounced that it is similar to two harpoons recently found in the peat at Holderness and dates from the Mesolithic period between the late Palaeolithic and the full Neolithic. The men who made these weapons are known as the Maglemose people (muckle-moss) who dwelt on pile dwellings on the western coast of the Danish island of Zeeland; and the Danish Museums have examples of the same type of harpoon as our North Sea specimen. A recent book states that these people lived on rafts or platforms made of tree trunks in the shallow waters of lakes and bays of the inland Ancylus Sea. 'During the closing phase of the Ancylus period the land rose so that the coast line was about 15 fathoms below its present level and the southern part of the North Sea became dry land; this enabled the Maglemose people to migrate as far west as Holderness.' This was written four years before the discovery of my harpoon and it is confirmed by this find which is therefore some 9,000 years old. But this does not complete the tale, as pollen analysis confirms the similarity of the peat of Holderness and Zeeland with the moorlog of the Lemon and Ower banks.

I must add a few words on the subject of pollen analysis, a subject on which I was completely ignorant before my interest had been aroused by my possession of the Maglemose harpoon. It has been found that the date of any peat formation can be approximately fixed by microscopic examination of the pollen enshrined in the preserving masses of peat. The pollens of oak, elm, birch, and pine can be readily recognized and a differential count made, which gives the proportion of the different kind of tree present in the forest that had laid down the peat. The dates of the various forests have been ascertained as characteristic of the flora of a particular period. In the case of moorlog from the Lemon and Ower banks, I collected specimens and these were examined at Cambridge and Copenhagen and the results compared with the peats of Holderness and Zeeland which tallied to a striking extent.

Details of this research can be found in the *Proceedings of the Prehistoric Society of East Anglia*. It is computed that this moorlog was 9,000 years old and thus we reach the intriguing conclusion that this harpoon is the first definite proof of the presence of Mesolithic man in the land bridge near the Dogger bank. Such a confirmation of the conclusions of workers in prehistory must be very gratifying to those who have laid the foundations of a new technique, and we are very grateful to the geologists of Scandinavia who have correlated the changes in the land surfaces of the Baltic with the forests of different epochs. Before dismissing the harpoon, it is a fascinating picture to portray this early man with his beautiful spearhead, so cunningly carved, now lashed to a long handle, spearing the flatfish in the estuaries of the large European rivers about to empty their waters into the North Sea; it may have been skate, a sting-ray or a torpedo, all of which are still harpooned on the coasts of both North and South America; or perhaps in the winter they may have gone for greater game such as salmon, as in Magdalenian carvings are to be seen the outlines of undoubted salmon as I have seen myself in the rock shelters of Les Eyzies in the Dordogne.

Chapter 17

FISH WITH ELECTRIC ORGANS

One of the most fascinating problems for the biologist is the production of electricity by fish and the power of specialized organs to produce shocks of sufficient intensity to kill or benumb their prey. Two examples may be given; a Torpedo, a fish not uncommon in British waters, has been caught in the estuary of the Tees containing an eel of two pounds weight and a flounder of one pound; another specimen had in its stomach a salmon weighing about five pounds, and in both cases there were no signs of external injury. There are quite a number of fishes of very diverse types that have these organs which differ in detail as regards their structure, but are all built up on a similar plan. To mention cartilaginous fish first, there are the Skates, the Torpedoes, and Rays; in the waters of the Nile there are the Elephant fish, the Mormyrids, and a Catfish widely distributed in Africa, while passing over to South America we have the Electric eel (*Electrophorus*) found in the Orinoco and Amazon. Recently, in addition to the above, the Star-gazer of the Mediterranean has proved to be another very interesting example (Norman). To approach a subject such as electric fishes without some first-hand knowledge would be presumptuous, and I can only claim to have been able to dissect one of these fish, the Electric eel, which by the way is not an eel but a Gymnotid, a species of fish closely related to the Carp Family. I had the exceptional good fortune to obtain a specimen from my friend Mr. Bourne, at that time Physiological Curator of the Hunterian Museum of the Royal College of Surgeons, who was helping me in some researches on the swim-bladder of fish. John Hunter has described this fish at length both as regards its electric organ and its general

anatomy, but there were several points left unexplored, because in his time microscopic technique was in its infancy. Starting where Hunter left off, I have been able to point out several important adaptations of function hitherto undescribed. Before detailing my discoveries in the anatomy of the Electric eel, I propose to give a short and simplified account of the typical electric organ. It may well be asked what evidence is there that these shocks, described as electric, are in fact electric. The answer is that they exhibit all the known powers of electricity: they render a needle magnetic, decompose chemical compounds, and emit a spark.

Mr. Wilfrid Trotter, whose death we have so recently deplored, and whose work *Instincts of the Herd in Peace and War* has already become a classic, was not only a great surgeon but a brilliant man of science and a philosopher. He has pointed out the imperative necessity for the nervous system to be insulated and in support of this he gives the example of the bulbous fibrous ending formed round a severed nerve, and describes how the special covering of the brain known as the *dura mater* is always replaced, with its special characteristics, soon after any injury has occurred. We have noted that the brain in fish has no *dura mater*, but as it fails to fill the cranial cavity it is protected by a gelatinous substance, which occupies the space between it and the wall of the skull. In electric fish two methods of insulation are used to protect the nervous element in the electric organ, the fibrous and the gelatinous, and the significance of the latter is made clear by the application of Trotter's principle. The electric current is derived from muscle, or at any rate a tissue evolved from muscle, and it is at the nerve ending in the muscle that this transformation of energy takes place. The relation of muscle to the formation of electricity was first suggested by Redi, but was dismissed by contemporaries with contempt.

The Torpedo is best described as being like an old-fashioned warming-pan, but the handle, as represented by the tail, is short and has two fins. The anterior portion is plump where

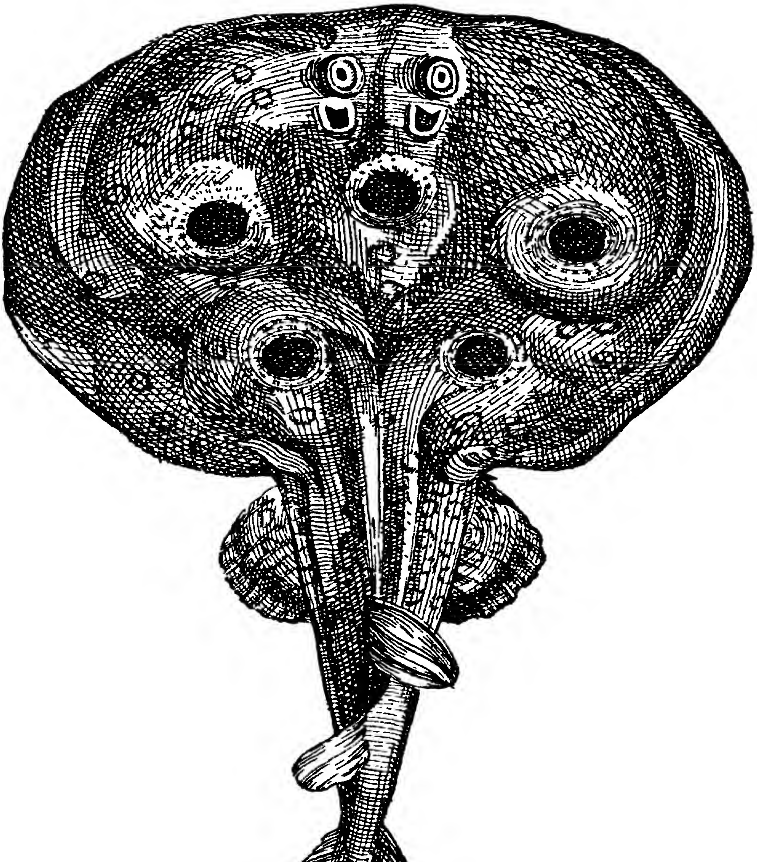


FIG. 27. *Torpedo ocellata* (After Willoughby)

the electric organs lie, one on each side between the head and the gills in the thickness of the pectoral fins. Recent research has shown that the muscles that are converted into the electric organ are connected with the gills. The Cramp fish or Numb fish are its popular names and refer to the effects of contact with this fish. The electric organ is a flat body supplied with large nerves and consists of vertical hexagonal prisms extending to the skin both above and below and each prism is further sub-divided so as to form pockets filled with a clear jelly-like fluid. When muscle is stimulated it has recently been observed that a definite chemical substance is formed at the nerve-end plate. In this way there is built up a battery which old writers said was similar to a 'Leyden's phial', to which we add the insulating jelly. The word phial refers to the supposed fluid nature of electricity. The strength of the discharge depends entirely on the health, size, and energy of the fish, and when the power is exhausted after some time, repose and nourishment are necessary to restore its function.

The Star-Gazer

Continuing our quest for fish with electric organs, we find ourselves once again on the shores of the Mediterranean Sea, this time at that end of the Riviera known as the Italian. Here it is not difficult to discover, even in the neighbourhood of frequented health resorts, some secluded fishing village where the population and their methods of fishing can be studied, and opportunities for investigating local fauna arise. Such a port lies within easy reach of Alassio, and its picturesque charm does not rest on dilapidation and decay, as is so often the case among the poverty-stricken mountain villages of Italy.

As the village is approached, you soon enter the narrow paved street, and are struck by the height of the buildings, which tower up on either side, four tiers of narrow slit-like windows piercing the honey-coloured walls, each window sunproof and sheltered by green or orange slatted shutters,

swinging on a central horizontal pivot. Opening on to the street were booths, shuttered or partly open to exhibit household goods, or products of the vegetable garden or plot, while the doorways were often decorated with fanlights of wrought iron, the curves and spirals forming an intricate design. A patch of colour was given to the otherwise bare street by bright cottons exposed for sale, and the love of flowers gave gaiety to an occasional tray of fruit of local growth. Passing on a few yards we reach a vaulted passage, the arch of which reached to the level of the second floor, and through this are seen a series of arches dwindling away in perspective, as successive small squares are entered. The largest open space or patio had the usual municipal offices and a War Memorial, and a restaurant belonging to a modest but pleasant hotel, with a gorgeous outlook, and a terrace abutting on the sandy shore, and with glass shelters to protect the visitor from the prevailing wind. Here one could sit and watch the longshore seiners hauling their nets, or wait for the return of the sardine drifters which can be seen fishing in pairs out to sea, or rounding the rocky promontory to the west. As one walks along the sand towards this point, the foreshore becomes strewn with rocks, and pools of shallow water lie between the fallen boulders which form a happy hunting ground for sedentary fish, crustaceans and molluscs and sea-anemones; and as Bridge would have said

> 'Twas here I stayed, and musing made my friend
> the melancholy sea.

An observer by lying on a rock and watching the life in the pools might notice a small reddish object writhing and wriggling at the margin of a slit-like depression in the sand, which might easily be mistaken for a worm. But closer inspection might show a suspicious pulsation in the sand and two periscopic eyes might be distinguished, emerging from the neighbourhood of the 'worm'. The association of this wriggling object and the two eyes suggested a lure, and the presence of a

hidden fish, and prolonged watching might repay the patient naturalist if perchance a small fish might venture too near the lure, when a gaping mouth might suddenly engulf its prey.

Such a bit of luck might find both prey and fish safely in the collecting bottle. The head of this small fish is box-like and if you picture a small box with its lid facing forwards and hinged at the bottom, you will realize the position of its almost vertical mouth, from which can be projected a red filament which grows from the floor of the mouth in front of the tongue. This artificial worm can be made to imitate all the wriggly and sinuous motions of the real thing, and proves an irresistible lure. The eyes are situated on the top of the head and are provided with the same hydraulic mechanism for protruding the eyes at will as is found in such fish as the plaice; this consists of a small sac containing fluid at the back of the orbit, which can be compressed so as to drive the fluid into a sac in contact with the back of the eye, and thus force the eyeball outwards. These thoughtful devices do not complete all the tricks that this sedentary fish has evolved. Unlike the weever it does not appear to trust its dorsal spine to attack its prey, although Bottard has described a poison gland at the base of the two first dorsal spines. It has called in an electric organ to stun or cramp its prey. Two oval areas of a considerable size are placed immediately behind the eyes, similar in design to the organs we have already described. But the development of these organs has recently been studied and it is established that the eye muscle has been converted into an electric plate and that each plate represents a single muscle. The strategic position is now complete and the upward glance of the eye, the lure, and the battery are all in train for a devastating attack on any unwary little fish that comes within range of the electric circuit. It is noteworthy that electric organs are not found in terrestrial animals and, further, it has been recorded that man has received a shock from a Torpedo without actual contact with the fish, so that it is possible that the prey may get its shock in its bath; and this suggestion is

more probable when we remember the number of fatalities in bathrooms with powerful electric installations.

The use of an eye-muscle for adaptation to an electric organ must receive some comment; to human anatomists the facial nerve and the facial muscles are very familiar and the public well know the ear trouble that is followed by facial paralysis; but it is not realized that a fish is an expressionless animal, and has no facial muscles, so there was no muscle available for the purpose of adaptation except an eye muscle.

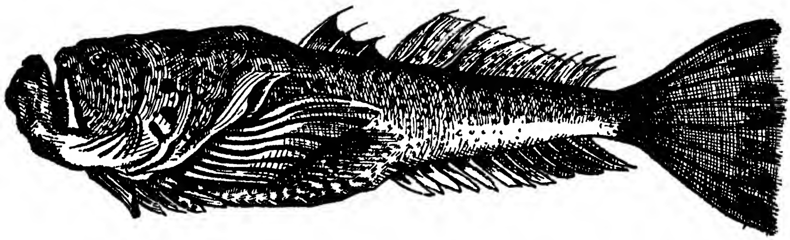


FIG. 28. The Star-gazer (*Uranoscopus*) (After Willoughby)

Uranoscopus scaber is the official name for the Star-gazer but some of the older writers called it the Stare gazer, probably from its fixed look; on the other hand does Uranus refer to the planet discovered by Herschel in 1781? Probably not, but is used in the Greek sense *ouranos*, heaven, so that Sky-gazer would be the more correct appellation. The answer to this conundrum is given by Willoughby, writing in 1686:

'*Oculi supra caput siti, recta coelum intuentur*', and further he says: '*Uranoscopus dicitur quod coelum spectat ob situm oculorum.*'

Electric Fish of the Nile

Passing from the Mediterranean Sea to the waters of the Nile we shall meet two large families, the Siluridae and the Mormyridae, in both of which we find examples of electric fish.

The family of Mormyridae is characteristic of the fresh-water fauna of tropical Africa. They have an organ on each side of the tail representing a transitional condition from muscular tissue to an electric organ. As in the other organs we have described, there is a capsule with numerous compartments divided into cells, containing a gelatinous substance. Like the Electric eel, Mormyrus loves to be eccentric and has obtained its aim by means of a phenomenal development of its brain, the weight of which equals one-fifty-second to one-eighty-second of the total, a thing not found elsewhere among the lower vertebrates. This increase in size is due to an enormous development of an anterior projection of the hind brain (the valvula of the cerebellum) the function of which is problematical. The strange formations of its snout have given rise to such names as horse, elephant, and ibis, and the terminal mouth is often very small and must limit its diet to minute worms, algae, and micro-organisms. But it pursues its likeness to the Electric eel by the development of its auditory apparatus. Through the kindness of Mr. Norman and the Trustees of the British Museum of Natural History, I have been able to examine a number of different species. There is an aperture in the skull in the temporal bone, closed by a thin osseous membrane, which acts as a tympanum, and beneath this is a drum shaped like an egg, against which lies a saccule or internal ear, containing an ear-bone or otolith, somewhat almond-shaped, which communicates with a smaller sac containing another otolith; this small cavity represents the lagena, which is looked upon as the precursor of the human cochlea. But the point that interests the comparative anatomist is that both Electric eel and Mormyrus have the anterior sac of the swim-bladder completely divided from the main sac of this organ; but whereas the anterior sac of the Electric eel has still a connection by a duct to the pneumatic bulb, Mormyrus has lost all connection and only a small tag represents the former attachment of the auditory vesicle or tympanum to the swim-bladder. To complete this picture of a perfect auditory

apparatus, we must mention that this fish has a large and well-developed auditory lobe in the hind-brain.

It will be noted that Mormyrus supplies further confirmation of the opinion that the anterior sac of a swim-bladder is an auditory organ as seen in the Carps and Electric eel. But in this fish the communication with the ear is direct and not through a series of ossicles as in the other families. The scepticism that has always existed as to the power of hearing in fish would perhaps have never been so wide-spread if Europeans had spent their boyhood on the banks of the Nile.

Our final example of an electric fish brings us to the family of the Catfishes or Siluridae. Silurus is derived from the Greek for a fresh-water fish and has nothing to do with the geological term Silurian which refers to rocks in a part of Wales occupied by a tribe called the Silures. Catfishes, like the Carps or cyprinoids, all possess a swim-bladder connected with the ear by Weberian ossicles; but unlike the Carps, usually have fin-spines both dorsal and pectoral armed and provided with poison organs. They all have barbels, sometimes like cat's whiskers and some stouter and shorter. They are devoid of scales but often have bony scutes. One species has an electric organ and is known as Malapterurus; this organ is built on a different plan from that of all the other fish we have described. There is a continuous coat of gelatinous material between the skin and the muscles enclosing the whole body. The electric plates are distributed irregularly within this and lie transversely. A single nerve fibre arising from a single large nerve-cell supplies the organ on either side; this nerve fibre is much branched, and ends in an electric plate. When we consider the relations of this jelly-like substance with the similar gelatinous material found in the electric compartments of Torpedo and the Electric eel and within the cranial cavity of most fishes, we feel that the conclusion is quite justified that its function is that of insulation and adds a striking confirmation of Trotter's view of the necessity of the insulation of nervous tissue.

Electric fish are relatively insensitive to electric shocks. This is probably due to the fact that the fish is a bad electrolytic conductor. Nevertheless it seems most probable that the careful insulation of both the nerve and electric parts of the installation must play a strong part in this partial immunity to shocks. It is known that in an electric ray described by Beebe, the points to be contacted to produce a shock were on either side of a central ocellus on its back. In connection with the question of immunity it is recorded by Mr. Walsh (Hunter's *Essays*) that 'two electric eels fought and bit one another, especially in the night. They did not appear to strike one another by their peculiar powers. This is like the bees which do not sting each other but bite.'

Another interesting point to be mentioned is the small amount of heat that is produced by the battery, and this recalls the heatless luminant of fire-flies and luminous fishes.

The Electric Eel

The northern part of South America contains in its large river systems an infinite variety of strange fish, among which are a large number of catfishes described in another chapter. But perhaps the most queer fish is an eel-like fish, which nevertheless is closely related to the carps, being in possession of a row of small bones connecting the front sac of the air-bladder with the internal ear. Another peculiarity of the Electric eel is a flower-like arrangement of projecting buds lining the roof and floor of the mouth, some of which grow from the upper margins of the branchial arches, and a further remarkable adaptation is the enormous size of the posterior bag of the swim-bladder. When we add to all these unusual characteristics the presence of an electric organ, we have a picture of an animal the make-up of which must have been dependent on somewhat unusual surroundings. The first of these is tropical heat, with periods of drought and sudden tropical rainstorms. The river may at one time be flowing over hidden sandbanks, and at other times large stretches of mudbanks may border

marsh or scrub with amphibious roots, stretching their tentacles into the muddy waters, and there may be large stagnant pools full of decaying vegetation. Everywhere the water, except in periods of flood, must be almost incapable of life, so devoid, as it must be, of oxygen and so full of the poisonous gases of putrefaction. In such a habitat the Electric eel has chosen to live and has made the best of a poor neighbourhood; it must be our aim to find out how he has mastered his difficulties. We can dismiss the electric organ in a few words, as we have already described the general type. Here we find that the organ consists of two parts on either side of the body from the tail forwards for about three-fourths of the length of the body, the upper part being large and the lower, on either side of the ventral fin, quite small. The columns lie lengthwise, not vertically as in Torpedo, and the cells number about 200 and are derived from skeletal muscle.

The swim-bladder is strangely adapted and, like all exceptions from the normal, provides additional confirmation to the views on its function which have quite recently obtained acceptance. As an example of a typical swim-bladder I have in front of me the swim-bladder of a tench removed from the upper and anterior part of the abdomen, and although removed without any care it still is quite air-tight; it consists of two bags, the posterior pear-shaped about three inches in length and at its widest part anteriorly about an inch and a quarter in diameter; it is attached in front to a much smaller bag by a narrow isthmus; this bag is an inch and a quarter in length and barely an inch in diameter. The isthmus between the two sacs is surrounded by a circular muscle, which constricts a small aperture usually closed; but the opening and closing of this sphincter muscle, as it is called, is controlled by a nerve centre, innervated by the vagus nerve. A careful examination of the smaller sac will show that the sac has two walls and that the outer, which is very friable, has been torn at its anterior end, and this tear has taken place at the only spot where the sac has any firm attachment, which is to a

supporting bone descending from the spinal column. Here also two small ossicles were attached but they also remained attached to this piece of bone where the tear took place. To return to the hinder sac, we can also see where a narrow tube starts from a spot below the sphincter at the widest part of the anterior convexity. This tube, known as the pneumatic duct, is guarded by a closing muscle, which is connected with the sphincter of the isthmus and is always contracted, and has thus prevented any escape of gas when the air-bag was torn out. This duct leads into the gullet which is also closed by a guarding muscle, which is part of a pump which can drive swallowed air into the sac. This pneumatic bulb, as it is called, consists of tubules surrounded by muscle fibres. If a fish is opened just after it has been swallowing air, a frothy collection of bubbles is seen in the gullet around the entrance to the bulb; this is sucked into the bulb and then pumped into the swim-bladder. This has been proved experimentally and by analysis of the gas in the bladder which has been refilled by the process of swallowing air. This is the normal state in the Carp Family but in the Electric eel the two sacs are not connected and the anterior is the only sac that finds itself situated in the abdominal cavity. The posterior sac lies beneath the electric organs, the two larger batteries of the back, and between the two smaller on either side of the ventral fin. It starts from the hind end of the belly, and extends to the commencement of the tail, and is like an elongated sausage. In the specimen that I dissected, which was three and a half feet long, its volume was fifty cubic centimetres; from its anterior end there arises a fine duct which passes forward to enter a large air pump or pneumatic bulb by which it communicates with the gullet. This is similar but much larger than that I have just described in the tench; it also receives a fine duct from the posterior end of the anterior sac which holds about two cubic centimetres. This lies in the front of the abdominal cavity which is so small that it does not form more than one-fifth of the body's length, and the vent is therefore just behind the

head. The anterior sac can be best pictured if a captive balloon is recalled, the single ovoid portion being nearly a sphere, and the two oval stabilizing projections less large in proportion. These two lateral projections give attachment to two small bones which are the first of a series of ossicles (Weberian) connecting the anterior sac with the internal ear. The object of these lateral bulges is to bring the surface of the bladder close to the cavity of the gill-chambers, and so more readily receptive of sound vibrations. The mention of sound vibrations may surprise the reader, because it is not widely known that my researches on the swim-bladder of the carp family have shown conclusively that the anterior sac is a resonator, which conveys vibrations, received through the body wall, and, by means of the ossicles, to the internal ear. This view has been adopted by an influential gathering of scientists in London, and has more recently been confirmed by the experiments of von Frisch, who has carried out a series of observations, conducted on the principle of Pavlov's conditioned reflexes, and shown that the range of hearing in a minnow is as wide as that of the human ear. He has also tested the range of hearing in fish with a swim-bladder of the carp type and found that the range of hearing was reduced by the removal of the bladder and concludes that 'those fish in which the swim-bladder is connected with the labyrinth (internal ear) by Weberian ossicles (as described above) have an apparatus by which the acuteness of hearing is increased'.

The function of the large posterior sac would at first sight appear to be hydrostatic and it might be called a buoyancy tank; but as this fish seems to be eel-like and fond of shallow water it does not appear to be advantageous to possess so large a tank. Another theory may be considered and that is that it might be a reservoir for oxygen gas when the supply of this vital gas is short. In fact is it an oxygen cylinder? This idea is suggested by the large posterior sac of the tench which I caught in a particularly foul corner of a stagnant broad. Another observation that may have a bearing on the air-

supply theory is that an analysis of the swim-bladder gases of a bream caught in the early spring soon after its period of quiescence in the mud showed that the percentage of oxygen had dropped to two per cent, a figure remarkably low. On the whole my mind veers to the oxygen cylinder theory.

We can now look at the interior of the mouth of this strange animal. In the floor of the mouth is a central raised portion bearing three parallel rows of flower-like bodies extending from the anterior teeth to the pharyngeal teeth, which we may observe are more like the dentition of a cod than a carp. The outer rows are larger than the central and their free margins are bordered with a crenulated frill. On the roof are more projections with wavy margins, and posteriorly three main fronds grow from the upper surfaces of the branchial arches, and a large cauliflower-like mass extends into a supra-branchial cavity. When the mouth is closed, it is found that these groups of excrescences fit into each other, and form a labyrinth of passages through which air, that is gulped, must slowly pass. The function of this maze of petals and papillae is made clear by the microscope. Before I had seized this opportunity to clear up the difficulty, Hunter had had to decide on a theory of its function but this remained a mystery. My sections disclosed that all this fabric was clothed with a delicate vascular tissue containing thin-walled alveoli, which has the appearance of a lung-like tissue. The papillae moreover contain large vascular spaces which communicate with a system of blood-vessels supplying the papilliform petals. We are now able to picture this amphibious animal whose love for aerial expeditions can be seen at the Aquarium at the Zoo if an obliging keeper will put his stick into the tank which it will at once start to climb up.

The significance of all these details concerning both swim-bladder and mouth-breathing apparatus makes very interesting reading. In the first place it is held by competent authority that the posterior sac is but a degenerate lung and that its respiratory function has been replaced by a hydrostatic

function, in fact it has become a buoyancy tank. It is known that if an organ once looses its original function, this can never be recovered, or regained; this is the explanation of the development in the Electric eel of a lung growing from its branchial arches. These pulmonary papillae demonstrate the persistence of function which is inherent in tissues, and enables these arches to obtain oxygen from water through the gills and if necessary obtain it from the atmosphere by means of these outgrowths. The anterior sac has always been connected with audition and its connection with the posterior sac was retained so that the pressure in its sac could be regulated, according to the depth and consequent pressure of water. In the present conditions this connection is unnecessary, as the fish is either in shallow water or under atmospheric conditions, and the only communication with the air can be obtained by the duct to the gullet, which has the function of the Eustachian tube in man, joining the middle ear to the pharynx. Finally we consider that the huge posterior sac is of little use as a buoyancy tank and that it has been made to subserve new conditions and to become a reservoir of air, in fact an oxygen emergency cylinder.

Chapter 18

JELLYFISH

Everybody knows that, strictly speaking, a Jellyfish is not a fish; neither is a whale and neither is a star-fish, but they all come under the heading of all that move in the waters. I feel constrained to include jellyfish in a book on stinging fish for personal reasons, as I have vivid recollections of unpleasant contacts, and for scientific reasons, as the venom, that can be extracted from the tentacles, has been the subject of important investigations, by French scientists in particular. This venom can be collected in large quantities, and in a pure state, and has been the means of obtaining accurate knowledge on a phenomenon called 'anaphylaxis' which has a wide bearing on problems of pathology.

In the summer the prevalence of certain winds proves favourable to the invasion of the coastal waters of the Pas de Calais by untold multitudes of the jellyfish, known as *Rhizostoma Cuvieri*. From Calais past Dunkirk to Zuydcoote is a favourite site for a collection of these Medusae to concentrate, and here they may make mass attacks on bathers, who are venturesome enough to risk the painful consequences.

There are two kinds of injuries that result from a bad sting or rather an extensive stinging; local, which are the most common, such as urticaria, like a stinging nettle only more intense, being accompanied by some pain and severe itching; general, namely constitutional symptoms sometimes grave and alarming; there may be shortness of breath and a feeling of anxiety. The difficulty of breathing diminishes gradually and gives place to a feeling of depression and extreme muscular weakness; these symptoms usually disappear in twenty-four to thirty-six hours.

On the other side of the channel we also get a lesser invasion in the summer, but although I have been a regular bather at Lowestoft for very many years, I have never come across severe cases of jellyfish stinging such as I have witnessed on more than one occasion on the sands of Dunkirk. In 1917, after the battle of Messines, I found myself in a Clearing Station at Proven and for a time things were pretty slack in the way of surgery, which gave those not on duty an opportunity to go down to the coast at Dunkirk 'with the washing'. As most of us had been working night and day since April behind Arras and the Vimy Ridge, and were now waiting for more arduous duties still to come, we gladly seized the chance of a bathe. I went down with two others on a sultry thundery day in July and found the sea smooth and warm, but soon found also that the sea was full of 'jellies', which were stinging us badly. One of us whom I will call X had been down about three weeks previously and had then been badly stung, but had only suffered from local burning, redness, and irritation. On this occasion X came out almost at once because, as he said, 'my legs and thighs seemed almost on fire' and rather thought he had a touch of the sun. He felt rotten with pain and became very sick. He had just strength to dress and go to a Field Ambulance, which we knew was only a few hundred yards inland. When he got there, he was short of breath, and his respiration was like that of a man with asthma. It became more rapid and it was with difficulty that he was able to draw his breath, until at last it became stertorous like a person in a state of coma. To breathe he had to be propped up. Meanwhile the pulse though slow was regular, but the legs were burning and the hands which had also been stung were painful and trembling. A feeling of anxiety and impending death overtook him as his breathing got still worse. Ether was given as an inhalation and the inflamed parts bathed with cold water, and cold compresses were applied. In the course of the afternoon the patient was fit to be driven to his unit at Proven in the ambulance. The difficulty of breathing was replaced by a painful curvature

of the lower part of the back and stiffness of the neck. The limbs were still burning and the redness and puffiness gradually subsided; where he had come in contact with the tentacles were little black spots and the redness and burning was intensified by immersion in cold water. On the way home he complained of pain in the throat and running from the nose, followed by a cough and a desire to be sick: which was relieved by bringing up a lot of clear and stringy mucus. The secondary symptoms were clearly those of a spreading congestion of the mucous membranes associated with a generalized febrile state. These symptoms gradually subsided in the course of the evening, although there was still some heat, and a certain amount of rigidity of the back. It is probable that the above case, so well described by the patient, was one of increased sensibility, the result of the attack three weeks previously. It is worth recording in detail, as it is a good example of the phenomenon now so well known to scientists by the work of Richet, under the term of anaphylaxis.

There is another method of introducing jellyfish poison into the human body. I have described it in lectures to local medical societies but as yet it has not found its way into any textbook that I know of. It is well known to the girls who mend the herring nets in preparation for the autumn herring fishing. After the summer herring fishing or Scotch fishing, as it is called, the fleet of herring drifters sailing out of Lowestoft return to mend their nets in preparation for the autumn fishing. This process is known as beating and it takes place in a beating chamber. The girls who do the mending are known as beatsters. It often happens that these nets have been shot when the North Sea is full of jellyfish. The result is that the desiccated bodies of 'jellies' have impregnated the nets with the dried venom of their stings, and it is well known that a dried venom retains its potency; the tannin of the net may also have helped to precipitate the proteins which as we know are toxalbumins. If the dust impregnated with this dried venom is excessive, an epidemic of 'jelly' poisoning occurs

among the beatsters. They suffer from sore throat, running from the nose, and symptoms simulating asthma. The boat-owners recognize the cause of the complaint and the nets are immediately taken out on the denes where the work is carried on in the open air. Here the venom is borne by the wind and dispersed. With the shifting of the nets into the open air the girls soon cease to be attacked by the above irritating symptoms, although some who seem to be particularly susceptible may be away from work for several days. It is important that this complaint should be recognized as the question of employers' liability might arise under the provisions of the Workmen's Compensation Act.

The substance responsible for the attacks on bathers has been isolated from the jellyfish *Rhizostoma Cuvieri*, the villain of the beach or sand. The medusae are crushed with sterilized sand and a little distilled water and allowed to macerate. The fluid is decanted and filtered. The addition of alcohol causes a precipitate which is collected, dried, and powdered. This powder can be redissolved and used directly for inoculation without any further preparation. When injected into a laboratory animal local swelling occurs followed by shortness of breath, weakness and often diarrhoea. Then shallow and intermittent breathing and death occur. Post mortem shows general congestion of viscera and lungs. The liver is enlarged and the intestines show haemorrhages. I have seen the same results in mice killed by weever venom.

The Portuguese Man-of-war Physalia is ovoid in form with a crest which acts as a sail. Its long tentacles are richly furnished with stinging cells. In the outer skin of the exposed parts are developed special cells, each consisting of a minute ovoid fluid-filled capsule, containing a spirally coiled hollow thread, often barbed near the base. Stimulation causes the expulsion of the thread which carries a poison and can pierce the skin. Some jellyfish show a remarkable example of altruism. *Cyanea papillata*, a beautiful blue 'jelly' which is found at the same time of year as that when the baby whiting is about an

inch in length, acts as a crèche for this toddler. Although their tentacles are furnished with batteries of stinging cells, under the shelter of these jellyfish the small whiting find a temporary home and escape from the jaws of predaceous fish. According to Russell and Yonge the Man-of-war possesses a specially designed float into which gas is secreted by a specialized gland. This gas-filled reservoir projects above the surface of the sea, and acts as a sail to this Jolly Roger of the ocean, roving the main.

Maladie des pêcheurs d'éponges or *sponge-divers' disease*

Dr. Zervos, in 1903, described under the above name a peculiar series of symptoms, which follow the contact of a little sea-anemone with the naked limbs and bodies of the sponge-divers of the Mediterranean coasts. Near the peduncle of the sponges, and more rarely on the large flat spreading species, there lives in commensal association with sponges a very poisonous anemone. One finds it at depths of 25 to 45 metres, usually where there is much seaweed. Its venom varies much with the nature of the environment and the time of year. According to the fishermen, this animal is most dangerous in August. The author, quoted by Phisalix, says: 'In man the first symptom which follows contact with this anemone is intense itching and heat, localized to the part touched, which spreads gradually to the whole body. A papule of hard consistence shows the site of the injury and all around this spot a redness appears which becomes purple and then black. This extends to a variable distance according to the quantity of the venom introduced, its virulence, and the part of the body affected. The skin sloughs away and is completely destroyed, leaving a deep cavity from which the pus pours, and antiseptic dressings are of little avail. Where the soft parts are loosely bound to the deeper tissues the destruction of tissue is very extensive. More rarely around the injured part there is a crop of abscesses arranged in a symmetrical manner,

which when opened discharge a quantity of pus and take a long time to heal. The onset of the illness is marked by fever, and a rigor at times; it lasts for several days and is accompanied by headache, thirst, and aching of the limbs.'

These effects of the poison have been repeated experimentally and confirm the fact that the symptoms are due entirely to the effects of the venom.

If taken by the mouth the results are well known to the fishermen, and are recognized as very toxic. They carry the polyp in a dried state from the northerly coasts of Africa where they mostly work and use the powder to poison domestic animals. The animals, to which a dose of actinie is given, die in a few minutes in violent convulsions.

The accidents which befall the fishermen from these stings do not confer any immunity on the sufferer, as can be judged by the scars which can be seen on all the old fishermen.

Chapter 19

MY LABORATORY

When I first started on my investigations into the uncharted backwaters of stinging fish, I was obliged to trespass on the kindness of scientific friends. My first guide was the late Dr. Sidney Martin who initiated me into the mysteries of M.L.D. (minimal lethal dose), a term used by the experimenters with snake venom and other animal poisons, which supplies a datum for estimating the effect of anti-venomous sera in neutralizing a venom. It was in his laboratory in the Pathological Department of University College Medical School that my first experiments on weever venom were made. The method of preparing and extracting the poison must now be mentioned; a very reliable fish buyer sent up from the market a trunk of fresh Greater Weevers for the experiments. These were washed under a tap with fresh water in my then makeshift laboratory. This was in a converted greenhouse leading out of my consulting room, and here a doorway opened into a lobby with basin and running water, several shelves, and a lavatory, while the main compartment contained a marble-topped table, an aquarium tank, gas stove, cupboards for reagents, an incubator, and sterilizer. On this table the weevers were laid out and the region of the gill-covers from which the poisonous spines protrude was wiped clean with sterilized swabs of wool. Into each groove at the side of the opercular spine was inserted an exploring needle, about the size of a small knitting needle, attached to a syringe and the contents of the gland sucked out. It will be clear that this involved four insertions into each fish and the time spent in extracting the poison from a hundred fish was a matter of a couple of hours. This procedure had to be under-

taken after a long day's work and usually lasted till midnight, and was further liable to interruption by a night call. Each time the needle was withdrawn the contents of the syringe were squirted into a watch-glass to which a little salt solution was added to facilitate the washing out of the venom. To preserve the venom I employed the method of drying which enables the investigator to have a supply of active venom handy for an indefinite time. Otherwise venom is very liable to become useless owing to the condition known as 'very labile'. The drying has to be undertaken in a glass desiccator which is exhausted of air and in the presence of a strong acid, in short 'in vacuo'.

This dried venom has to be redissolved before it is required for inoculation. The next step was the provision of an experimental animal and this was obviously some species of fish: living within easy reach of a broad, it was usually possible to get fresh roach from a professional fisherman, who provided live bait for pike-fishermen. We may again note the strangeness of legislation that allows fishing with live bait, but insists that the inoculation of a fish can only be undertaken under licence and in an approved institution. Presumably the roach likes to get its own back on the pike by altruistic aid to the sportsman. Failing the live-bait merchant, or during the close time, it was necessary to drive some fifteen miles to a private broad, which was used for stocking other areas and did not come under any Fishery Board jurisdiction. Failing this source of supply, I have fallen back on the people who provide food for the fish-eating birds of the Zoological Gardens. The venom and live fish had then to be taken up to London, where my accomplices were awaiting my arrival. Here my friend Dr. Stevenson made injections into roach and mice, and I recorded the results and we established the effects on these animals, which were paralysis of the muscles at the site of injection, congestive action on the viscera, often with intestinal haemorrhages and later local death of the part, necrosis with suppuration, followed by death.

French workers, particularly Briot, had however carried the research further and had employed a method of investigation which could be carried out without any restrictions and in one's own laboratory. This method uses the phenomena of haemolysis or the dissolution of the red corpuscles of the blood. This method had been largely used in the study of immunity and the famous Professor Ehrlich, under whom I had studied in Berlin, had provided the worker on venoms with several chapters of detailed descriptions of observations on cobra poisoning. I followed these details in my studies on weever venom. To examine human blood I bound a handkerchief round the base of one finger and pricked the tip deeply. The drops of blood were allowed to fall into a test tube which fitted into the aluminium holder of my centrifuge, and contained citrated salt solution of the same specific gravity as blood serum. A few cubic centimetres of blood were soon collected and the solution was then centrifuged. After a few minutes the 'water centrifuge' had precipitated all the red cells; the tube was removed and the supernatant fluid was pipetted off and fresh salt solution was added; the tube was returned to the centrifuge and spun again: this process was repeated till all trace of serum was removed and finally a five per cent solution, or rather suspension of red cells in normal salt solution, was made. Into a series of long narrow test tubes equal quantities of this suspension were poured. One was left untouched but into each of the others one, two, or more drops of weever poison was added. The weever venom in these experiments had not been desiccated, but fresh venom was available to which a few drops of glycerine had been added. All the tubes were then placed in an incubator and there stood in a rack upright and allowed to remain at a temperature of the body for two hours. The rack was then removed and, after a short time to allow all sedimentation to take place, the results were noted. If the venom was active and in sufficient quantity the tubes would be uniformly coloured a deep red and some yellowish sediment was at the bottom, but if the

venom was inactive all the red cells collected at the bottom and the supernatant fluid was quite clear. The extent of the dissolution of the corpuscles is thus estimated according to the tint of the supernatant fluid and designated slight, moderate, or complete haemolysis.

With this technique I tested the blood of fish, pigeon, sheep, dog, horse, ox, and man, and in all I obtained definite haemolysis. These results were contrary to those of the French observers. It was necessary to investigate the discrepancy. The French results showed that haemolysis did not occur unless heated serum was added to the solution; the method of preparing the venom for the experiment proved to be different; the poisonous spines were crushed in a mortar and glycerine added; this was then passed through a porcelain filter and this filtrate used. What would happen if I passed my glycerinated venom through a filter? The answer was soon given. There was NO haemolysis with the filtered fresh venom, but if I added heated serum haemolysis took place. Something obviously was separated in passing through the filter, and this could be recovered if salt solution was added to what remained in the filter and further filtrate obtained; this salt solution had the same power of activating filtered venom as did the heated serum, and our next object was to take these washings and investigate their contents. From the washings there can be precipitated a substance, by adding an excess of alcohol; this substance acts like a body called 'complement' which unites with another substance, before haemolysis can take place. This leads far from our subject and launches one into the controversies of the problems of immunity. However, there is one very interesting point to be recorded in connection with the action of a filter on venom.

In the course of their studies on anti-venomous sera such as is used in the treatment of diphtheria, when it is called antidiphtheritic sera, it has been found that when this serum was passed through a Berkefeld filter, complement is largely retained in the pores of the filter, whereas what is known as

immune body passes through practically unchanged. We will leave the theory here and tell of a sad effort to advance the knowledge of weever venom. Professor Martin of Cambridge came to my help and gave me details of a method for exploring these labile substances. The experiments had to be conducted at a low temperature, and in spite of the purchase of a refrigerator, there was no Frigidaire in those days. It seemed to me that I could get over the difficulty by carrying my refrigerator down to the East Anglian Ice Works where my friend the Manager was prepared to let me use his refrigerating plant. I took my venom and my reagents, and all the paraphernalia, and installed them in the Ice House. Then came a convenient slack period in my practice and on Easter Monday, with sandwiches, a thermos flask, and a fur coat, and several sweaters, I was locked in my Arctic lab. Here the alchemist spent twenty-four hours and a series of experiments were carried out according to plan; but owing to the insolubility of the precipitate I was working with, definite results were not obtained. The summer passed on and the time for more weevers to be caught arrived, but meanwhile the rumours of war, followed shortly by hostilities, caused strange vessels to be moored alongside the quay of the Ice Works, and one steam yacht arrived manned by Cambridge undergraduates. In the interests of the cook-house rather than science, they ransacked the premises, and finding a perfectly good refrigerator, annexed it, not stole it, but wangled it; and so ended for the duration my apparatus. It will not be surprising when I state that the yacht and refrigerator came to a watery grave.

Chapter 20

TREATMENT OF WOUNDS

The treatment of wounds produced by venomous fish is the same as that for snake-bite. If the immediate treatment be efficiently applied there will be no need for an anti-venomous serum because in the case of fish the quantity of poison injected is usually small and the general symptoms are seldom sufficiently grave to need the neutralizing of the poison in the blood by an anti-venomous serum. Nevertheless Briot has prepared an anti-venomous serum; he has immunized rabbits against weever venom by means of inoculations, at first subcutaneous, and later intravenous, of the venom. The serum from these rabbits was found to be anti-venomous and could be used, when mixed with the venom itself, to obtain immunity.

From earliest times fishermen have believed in the efficacy of the liver and flesh of Scorpion fish and Weevers applied to the wound, as an antidote, and we have referred to their belief in the virtues of sting-ray oil. The Pacific fishermen believe in the local application of the leaves of *Abrus precatorius* for the stings from Synanceia both in Réunion and in Mauritius. The ideal treatment rests on the fact that all these venoms are of the nature of toxalbumins and are very labile and readily destroyed by permanganate of potash and chloride of gold. The permanganate treatment is the same as that introduced by Lauder Brunton for the treatment of snake bite. The apparatus required is a small wooden case which holds at one end a small lancet and at the other end a screw-topped receptacle for a few crystals of permanganate of potash (Condy's Fluid). This is well known as Lauder Brunton's snake-bite lancet and has saved millions of lives in India, South Africa and tropical

countries. A more efficacious apparatus has been made for me by Brady and Martin; it consists of a small all-glass hypodermic syringe with two rustless needles, and three small ampoules of five per cent permanganate solution in a metal case. As soon as possible after the injury, the injured part should be cut off from the general circulation by a ligature, handkerchief, string, or bandage; as the sting is usually on the hand or feet this is easy. The wound is then deeply punctured with the lancet, the crystals rubbed in and moistened or spat upon. If the hypodermic apparatus is available, the tip of an ampoule is broken off, the fluid drawn into the syringe by the needle, which is then plunged into the wound, and the antidote injected. The relief from the acute agony if treated in this way is almost instantaneous, and the pain disappears as if by magic. The efficacy of this treatment has been established by many personal observations, and in the neighbouring fishing ports the medical men have adopted it with great success, as their letters to me substantiate. The local chemists keep a supply of the apparatus, both the lancet and the syringe, and consequently few cases now reach the surgeries of the resident medical men. The Board of Trade used to include the details of the permanganate treatment in the first-aid outfit that fishing vessels are supposed to carry, but whether these instructions are now given and carried out is not within my knowledge. When I was still in practice, it was not unusual for those fishermen who had had experience of the efficacy of the syringe to come to the surgery for fresh supplies of permanganate ampoules. The following is a record of a case of sting by a Lesser Weever which happened to my younger son when eight years old. While bathing a few yards from his home, he was stung in the foot and was brought home crying and in great pain. I happened to return to the house shortly afterwards, and having found the wound, immediately carried out the treatment as above described, using the hypodermic needle and permanganate solution. The condition of the boy was alarming as he was very pale, with a rapid feeble pulse and

cold sweats. He seemed beside himself with pain and the insertion of the needle into the wound was not even noticed. Within a few minutes of the injection the pain was completely relieved, and after a glass of hot milk he was anxious to return to the beach. After an hour's rest he was allowed to join his fellows; no swelling or inflammation followed the sting, as its virulence was at once destroyed by chemical means.

It will be clear from this description that local treatment, if promptly applied, is most efficient, and it points to the conclusion that the preparation of an anti-venin against weever venom, though possible, is unnecessary. What is most necessary, however, is the realization by the public of the dangerous potentialities of these stings, and the knowledge of the treatment, which is the same for all fish venoms. Once this knowledge becomes widely known we shall cease to hear of grave disabilities as the result of these injuries, while mutilated hands, the result of the inflammation that follows untreated cases, will be seen no longer.

On the nature of fish venoms

It is known that bacteria are capable of giving rise to poisonous substances within the animal body, and also in artificial media such as broths, gelatines, and even on the humble potato. Very little however is known of the nature of these bodies, and therefore we apply to them as a class the general term 'toxins'. These bacterial poisons belong to a group of toxic bodies all very much alike, other members of which occur widely in the vegetable and animal kingdoms. We have already mentioned Abrin, which is obtained from *Abrus precatorius* (Jequirity) and noted its empirical use by the fishermen of Mauritius and Réunion as a remedy against the effects of a prick by Synanceia. Muir and Ritchie state that 'its chemical reactions correspond to those of the bacterial toxins: they are soluble in water, they are precipitable by alcohol, but being less dialysable than the albumoses, have been called toxalbumins. Their toxicity is impaired by boiling, and they

gradually become less toxic by being kept. When injected subcutaneously a period of twenty-four hours elapses before symptoms set in.' The following symptoms may arise, great inflammation at the site of inoculation, which may end in local destruction of the tissues, blood-stained diarrhoea, and inflammation of the kidneys and mucous membranes.

It is also known that the poisons of bees, scorpions and snakes belong to the same group and the previous pages will have shown that the poisonous secretions of the weevers and many other fish must no doubt be classed among the toxalbumins. As I have already mentioned, Richet investigated a toxic substance obtained from the tentacles of Actiniae, to which from its action he gave the name Congestin. It was this study that first drew attention to the phenomena of anaphylaxis, and in the chapter on Jellyfish I referred to the experiences of a young surgeon who had a nasty lesson, the result of taking the risks of a second sting shortly after the first. The result of the sting, three weeks after the first attack, was to produce violent symptoms of Congestin poisoning. Richet found that he could further analyse the toxin and he obtained two substances, Actino-congestin and Thalassin. The first is obtained from a solution of the tentacles by precipitation with alcohol and the second by treating the tentacles with alcohol for several days, from which he obtained a gummy substance which eventually precipitated some crystals. But the details of the process need not be recounted here. This is one of the first attempts to analyse a toxalbumin, a term which does not after all do more than designate a substance of various properties, mostly harmful to protoplasm. It does more than this, however; it suggests further attempts to discover the nature of the secretions of poisonous animals. I do not claim to have gone very far in this direction, but having 'messed about' for years with weever venom, have observed a sudden transient reddish coloration appear when I added ether to an alcoholic extract of this venom, from which I later obtained a gummy substance. The quantity with which I was working did not allow any further

stages to be reached, but when it is realized that Richet required at least ten kilogrammes of tentacles to extract sufficient material to obtain his crystals, the number of weevers required can be left to the imagination; as it is only possible to extract one or two minims from each opercular spine. I feel convinced that a whole-time worker in a big fishing port might in normal times repeat the method of Richet with a sufficient number of fish to provide the requisite amount of venom.

Before turning to further observations relating to the chemical constitution of venoms, it would be well to summarize the knowledge we have obtained from microscopic examinations of the venom and the stages in their secretion as recorded by different observers. Bottard, describing the poisonous secretion of Synanceia, notes the appearance of large free cells scattered in an albuminous fluid; he has seen in the free cells, which he calls globules, a great number of fine granulations and occasionally a nucleus. In the venomous secretion of the weever he found leucocytes and 'cellules refringentes' as well as some large cells with nucleoli within their nuclei. I have seen all these cellular elements in the venom of the Greater Weever, extracted with an exploring syringe, but I have been still more fortunate in obtaining a section of the base of the poison gland in an active state of secretion. I showed these sections and microphotographs of them, at the Meeting of the British Medical Association at Newcastle in 1920. The section of which I reproduce a drawing here shows more detail and puts in their proper relation the different structures seen in the course of their secretion. The outer layers of the gland show large columnar cells, while towards the centre are seen cells distended with refringent material which stains yellow with van Gieson's stain. This highly refractile substance is discharged from the cells as opaque globules which lose their yellow stain and burst into a number of fine granules that take on a bluish stain with haematoxylin. These larger cells I have called 'shrapnel' cells and the granules represent the bullets discharged by the bursting shell.

Other observers have studied the microscopic appearances of the venoms of Scorpion-fishes and Catfishes, and have described the same elements in their secretion. The secretion of Scorpion-fish consists of cells, columnar, conical, and club-shaped, very large and often showing refringent filaments projecting from the open end of the cells. The secreting cells of the axillary glands of Schilbeodes and Noturus have also been referred to as very large.

We find therefore that in Poison-fishes, Scorpion-fishes and Catfishes the same type of secretion and the same symptoms follow a sting in varying degrees of severity.

It has often been asserted that the slime or mucous cutaneous secretion of fish may be the cause of the pain and other symptoms that arise after a prick from their fin-spines. There does not seem much evidence to support this view; it is of interest however to mention that it may occur in the fish Synanceia verrucosa, but in this case it is not merely the mucus of the skin, but the result of a special modification of skin-glands, which have given rise to the 'warts'.

In tropical Queensland this fish (*Synanceia horrida*) is called the 'warty ghoul' or stone-fish. The warts are said to eject a tinted milk-like fluid of an irritating nature which can be squirted a distance a foot or more.

Before discussing the venoms of the Rays and Sharks we propose to refer in some detail to the relation of pigment to certain other substances that have a physiological action sometimes poisonous but always of great importance in the animal kingdom. We refer to melanin, adrenalin, and tyrosin, and we shall endeavour to make the matter as simple as possible. We have already mentioned that the Cephalopod known as the cuttlefish (Sepia) produces from its salivary glands not only a crab-poison but also an inky fluid that can produce a protective screen. The pigment obtained from the latter is used by artists to produce a brown or black paint; according to von Fürth this pigment is a 'melanin', which is formed in the cuttlefish by the action of an oxydizing enzyme (ferment)

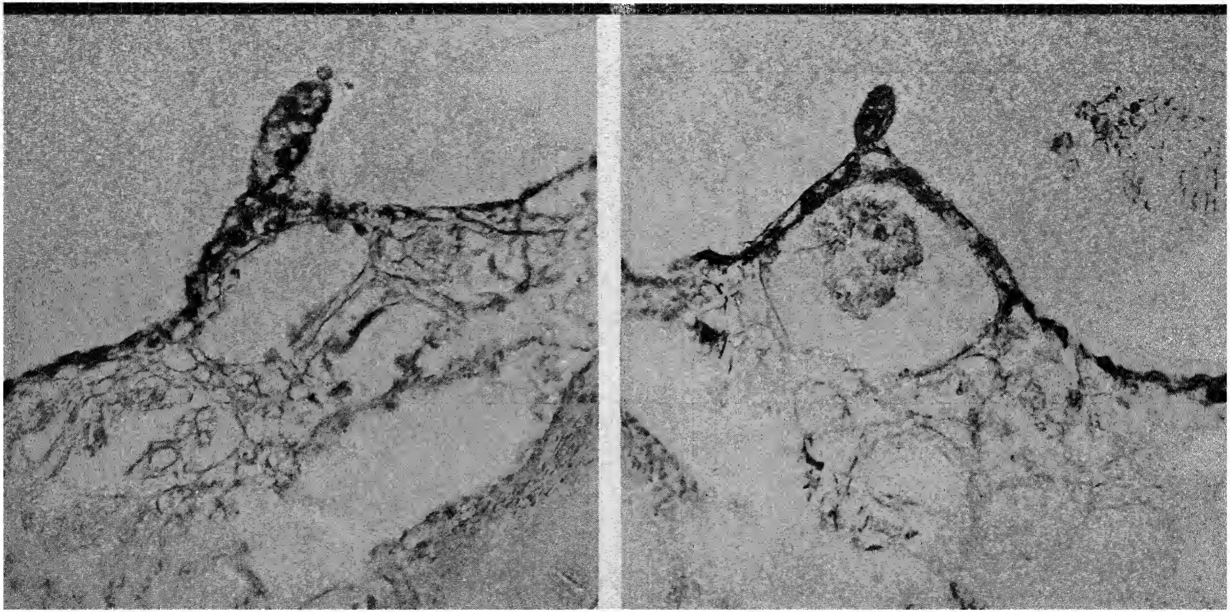
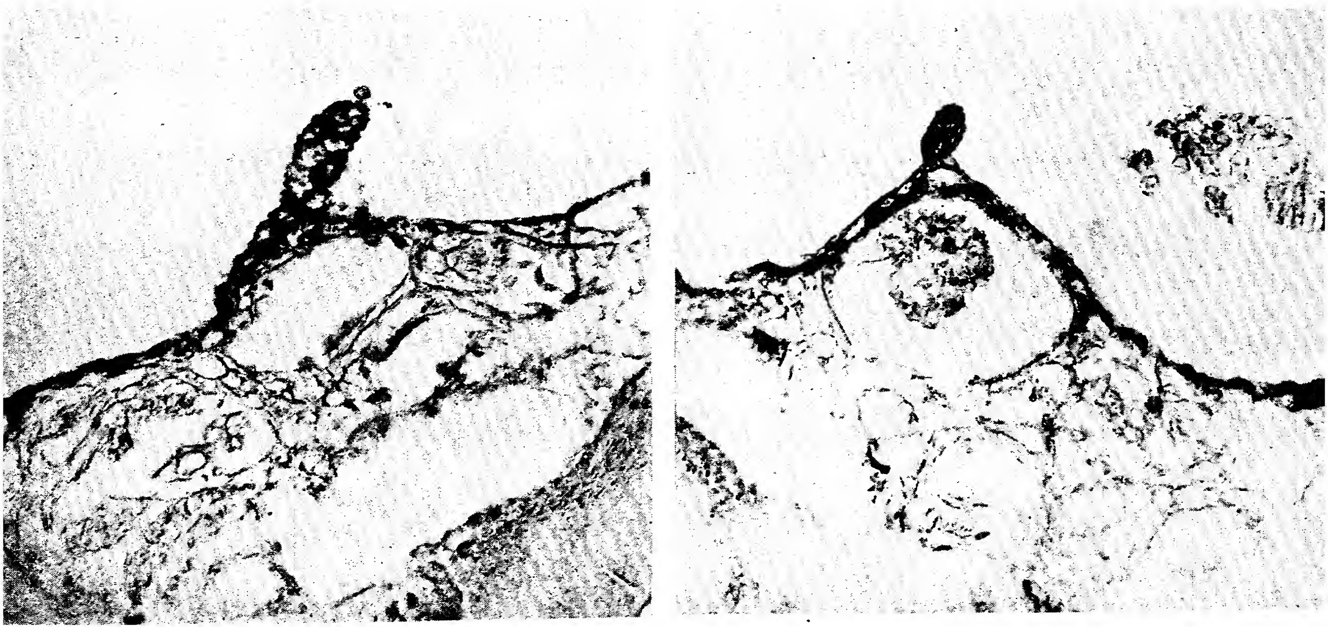


PLATE VII

Two sections of the outer margin of the deep layer of the gland of the lateral groove of the Sting-ray showing the lateral canals and the pigmented layer of blood vessels. They present a nipple-like appearance. To the left the canal is small and the nipple swollen while on the right the canal is distended and contains amorphous substance while the nipple is small. On the right side of this are fragments of the secreting portion of the gland which have become detached in the process of decalcification (high power).



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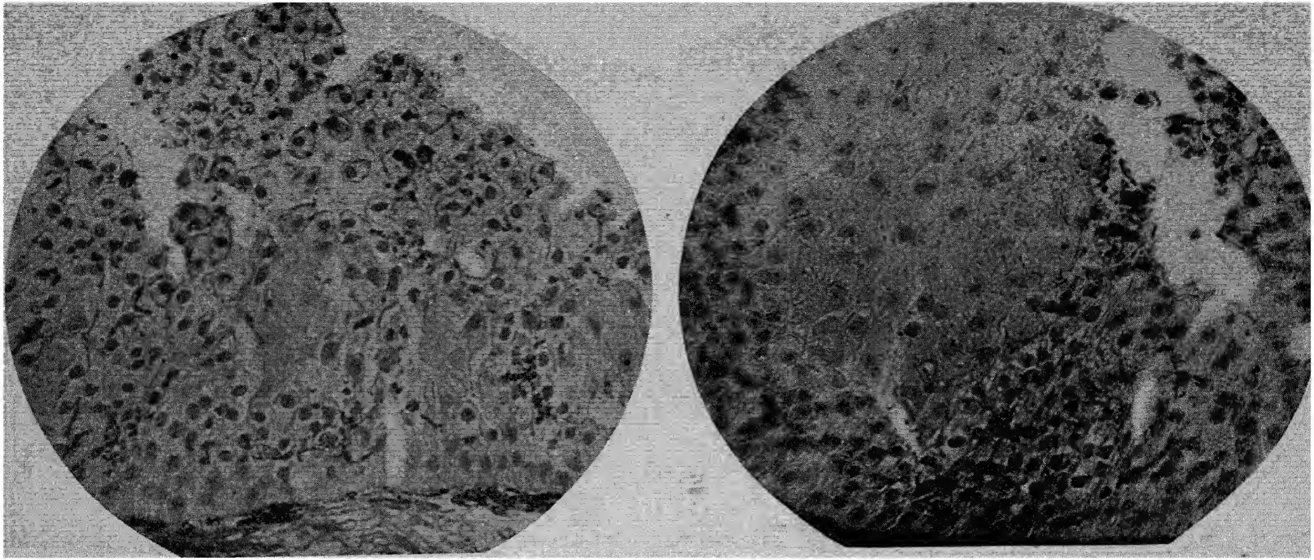


PLATE VIII

TWO SECTIONS, HIGHLY MAGNIFIED, OF THE POISON GLAND OF THE STING-RAY SHOWING STAGES OF SECRETORY ACTIVITY

(*a*) Portion of the gland of the caudal spine of the Sting-ray showing columnar cells resting on pigmented capillaries. Above these, cells in various stages of secretory activity, and pigment granules.

(*b*) A portion of the same gland in which the left half is composed of the distended cells with faint outlines and indistinct nuclei, indicating an advanced stage of secretion.

in the skin and mucous membrane. Much more of interest in the subject of poisons in toads and lizards can be studied in the masterly work by Marie Phisalix, which describes the relations of these venoms to the drugs acting on the heart such as digitalis and strophanthin.

It is a very fortunate thing that melanin, which seems to be the possible precursor of a poisonous substance, should betray its presence by appearing as a black pigment. This brings us to the consideration of an interesting occurrence, namely the presence of pigmented blood-vessels in association with poison glands. We have already described the pigmented capillary blood-vessels (the 'réseau capillo-pigmentaire' of Phisalix) of the Salamander and my own observations of the presence of similar pigmented vessels in the sub-epithelial tissue of the poison gland in the groove of the spine of Trygon; this layer of vessels is prolonged into the protective flaps that lie over the gland towards its apex, but they also appear as covering nipple-shaped extensions of the lateral canals,[1] and it seems probable that they may be a source of supply of material for the secreting gland. This is the more probable since we have noticed, surrounding the gland cells in an active state, chains of pigment granules and larger masses of pigment, which appear to be the material from which the venom is built up. If there is any truth in this suggestion it would seem that the venom should be of a similar chemical nature to that of the cephalopod; when the symptoms of the two poisons are compared it is found that in both the symptoms of convulsions followed by paralysis are manifest, but the question of the existence of acute pain cannot be compared as crabs have no means of expressing this emotion. To conclude this question, it is important to recall that Baglioni compared the symptoms of crab-poison with those produced by carbolic acid on the frog, and suggested that the saliva of Octopus derived its action from a 'phenyl' derivative. This was the hint that led to the discovery by Barger and Dale of parahydroxy-PHENYL-ethyl-

[1] See Microphotograph.

amine. This substance is not specific for Crustaceans but acts equally rapidly on other animals and is strongly neurotoxic. De Rouville has made experiments on dogs and has recorded cases in which the phenomenon of anaphylaxis was obtained. If these results are confirmed it would throw doubts on the accepted view that anaphylaxis is not known to occur as the result of poisoning with any substance of known chemical constitution.

I will conclude this history of Fish-venoms by an account of some experiments I made some years ago on the use of abrin, by the natives of Mauritius, as a remedy against the poison of Synanceia.

We have described how weever venom causes dissolution of red corpuscles or haemolysis. Experiments were made to see the effect of adding a solution of abrin to a suspension of red corpuscles to which a few drops of weever venom had been added. It was found that very definite diminution of haemolysis took place, and that the diminution of the toxic effect was proportional to the amount of abrin added. It was also noted that there was marked 'clumping' of the red cells (agglutination), which seemed to be the protective mechanism. Experiments on small animals also showed that life was prolonged if abrin was injected at the same time as a fatal dose of weever venom, but yet the animal died. But it was noted that whereas the injection of venom alone was always associated with marked haemorrhage at the site of injection, yet if abrin was also injected at the same time there was *no bleeding*. This suggests that abrin is a definite protection against haemolysis. I must add an experiment by Calmette which has some connection with this effect. Rabbits vaccinated against abrin can withstand a dose of cobra venom which would be lethal in one hour. In this case there is a passive immunity, whereas in my experiments there is evidence of an active immunity. There is an old saying, 'Similia similibus curentur'—Like may be cured by like. This may be another of nature's hints.

Chapter 21

THE DORSAL FIN-SPINE AND HUNTING EQUIPMENT

It has already been mentioned that the dorsal spine of the weever is a very formidable weapon, nevertheless this fish often falls a ready prey to other carnivorous fishes, in the stomachs of which it is not infrequently found. In the invertebrates we constantly find examples of poison-organs which are weapons of offence, if that term can be properly used for the stings of jelly-fish and spiders, which are part of their hunting equipment.

With few exceptions, one of the most characteristic results of the inoculation of venoms of these animals is paralysis, and in those fish in which it has been possible to make laboratory experiments with their venoms, it has been found that the same paralytic effect is produced, and further in those cases in which no experiments have been made, we read of accounts by skilled observers of paralytic symptoms occurring in their patients. We shall now give arguments to show that the dorsal fin is frequently modified for hunting purposes. Three examples will be given, the Angler or Fishing-frog (*Lophius piscatorius*), The Rockling (Motella), and the Forkbeard (Phycis) the last two being members of the Cod Family (Gadidae). The Fishing-frog is not uncommon on our shores and is so called because the first dorsal fin is converted into a whip-like filament, at the extremity of which there is a lure, and this is dangled in front of its capacious mouth; as soon as inquisitiveness prevails over caution, the unwary prey is engulfed in this oral abyss. In deep-sea fishes there is a still more complex and efficient evolution of the fishing device. Norman in his book *A History*

of Fishes gives a good plate of some of these *Ceratoid* angler-fishes, which, as he says, 'spend their lives in more or less perpetual darkness', and in which the bait generally takes the form of a bulb of varying size, which can be made luminous at will. In one species, *Lasiognathus saccostoma*, the basal part of the dorsal fin-ray has been converted into a stout rod, followed by a slender line which is provided not only with the usual luminous bulb, but also with a series of curved horny hooks: a veritable 'compleat angler'.

The rocklings, which live among rocks near the shore, have contrived an ingenious device for luring their prey within reach of their jaws. Where the anterior dorsal fin usually lies is a longitudinal chink which at first sight seems to be lined by a row of very short hairs; at the anterior end of this row a thread or filament, about a centimetre or so long, projects vertically and is in constant motion even when the fish is at rest. The hairs are actually the fringed margin or fimbriated edge of an undulating membrane which extends the length of the chink. This organ has for a long time been imperfectly understood but it is now known to be supplied by a special branch of the seventh nerve which leads, as I have recently shown, to a greatly enlarged lobe of the hind-brain. The membrane is also furnished with special sense-organs known as taste-buds, which reveal the presence of sapid substances in the water. The mechanism of this hunting equipment is the attraction of the prey by the filament, which is mistaken for a small worm, and the carrying of the taste of the prey to the taste-buds in the stream of water, produced by the wave movement of the membrane. All sensations of taste received by the seventh nerve, including those from the barbels, are known to be carried to the medulla oblongata which in the rockling has its facial lobe very large. The forkbeards (Phycis) are also members of the Cod Family, and there is a member of this group which is of a sedentary habit, and has in addition to the long filaments of the pelvic fins, one of the dorsal fins prolonged into a similar filament. This would

appear to be of value in its search for food. The conclusion is therefore reached that there is an inherited function, inherent in the tissues, from which the dorsal fin is evolved, and this may lead to a variety of forms of hunting equipment—either a simple dart, serrated, or envenomed, a fishing apparatus of startling originality, or a special detective apparatus for ensnaring the prey. There are numerous other examples of the varying adaptability of an 'area-tissue' in the maintenance of a particular function, for instance the tissue that surrounds the entrance of the pneumatic duct into the swim-bladder will, if the duct atrophies or becomes ineffective, proceed to form a *rete mirabile* which is able to produce the gases formerly supplied by the duct; this we have observed in the pike.

The Fin-spines of Fossil Fish

An interesting result of our observations on the spines of sharks and Chimaeras is the light they throw on the function of those fossil fin-spines known as ichthyodorulites (*ichthy*, fish, *doru*, spear).

The remarkable history of that famous collector, Mary Anning, the pioneer worker in the Lias of the cliffs of Lyme Regis, can be read in a recent number (1939) of the Dorset Archaeological and Natural History Society's *Journal*. Her friendship with Buckland, the first professor of Geology in Oxford (1819), and with Conybeare are here recorded, as well as the remarkable contributions to the science of palaeontology which resulted from her pioneer work. Mary Anning was not only the discoverer of the Plesiosaurus, but she unearthed the dorsal fin-spines of Hybodus which were found in close proximity to its teeth, and in this connection she became acquainted with Agassiz whose work on the fossil fishes of the family of Hybodontidae (nearly related to the Heterodontidae) is well known. This family contains two fossil fish with very remarkable dorsal spines, which are pictured in Zittel's *Text-book of Palaeontology*, but I have had the opportunity of examining and drawing two finer specimens in the collection

at the British Museum (Natural History) through the kindness of Sir Arthur Smith Woodward. These drawings and others illustrating this chapter first appeared in my paper in the *Philosophical Transactions of the Royal Society of London* (Ser. B, Vol. 1212, 1923).

The following observations on ichthyodorulites are the result of visits to the museums of London, Oxford, Cambridge, Paris, and Exeter. In the last-named museum, which has the unique advantage of proximity to that Mecca of geologists, Lyme Regis, I was not only able to view the specimens but to carry away 'spare parts' given by many local donors. These, together with the drawings I was allowed to make at the British Museum and with the assistance of Zittel's textbook, form the basis of this short and necessarily incomplete review of the subject.

The connection of fossil fin-spines with their former owners is possible owing to the discovery of complete skeletons; another clue to their connection is found in the association of spines and teeth in close proximity, as in the identification of species the teeth of sharks, in particular, are of great value. Furthermore it is very fortunate that certain forms have remained practically unchanged even from Cretaceous times to the present day; for example there are two sharks and several Chimaeroid fishes now living whose Cretaceous ancestors would recognize at once as descendants or near relations. These spines consist of dentine or vasodentine, the name given to dentine traversed with numerous blood-channels, and these are assumed to belong to the Selachii (Greek: *selachos*, a cartilaginous, not bony fish), and are frequently found isolated in Palaeozoic formations. The Selachians are now divided into five main sub-classes. The first three contain only extinct forms, the fourth includes all the existing sharks and rays, and the fifth the Chimaeras and their allies (Norman). It is with these two sub-classes that we shall find most of the fin-spines in which we are now interested.

All the remains that can definitely be ascribed to sharks and

B

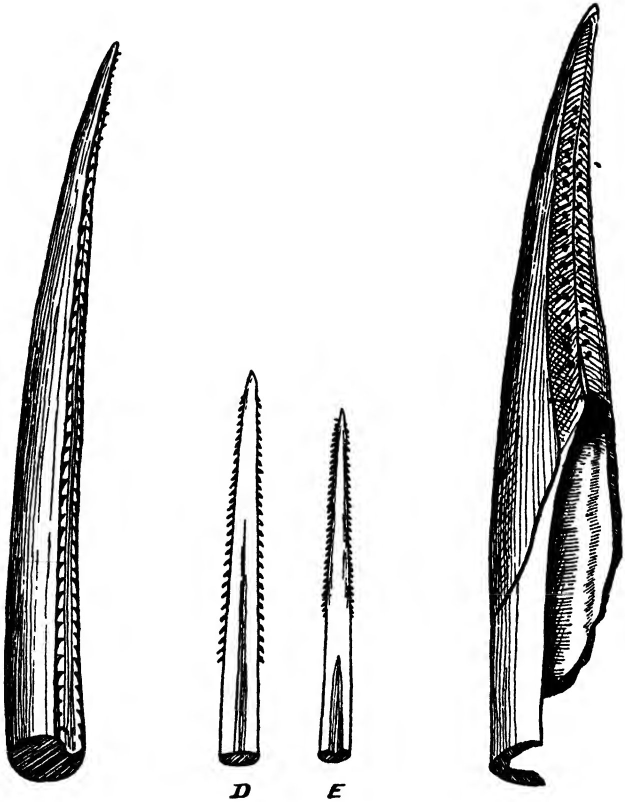
FIG. 29. Asteracanthus ornatissimus (*Cestraciontidae*)
B Three-fifths natural size. B.M.Nat.Hist. The curved and hollow spine has a convex anterior aspect which is enamelled and embossed. The posterior aspect has a median ridge with two rows of recurved denticle separating two rough concave surfaces.

rays have come from the Triassic and subsequent periods, although some fragments may have belonged to sharks of the Carboniferous and Permian strata. All the families of existing Selachians with few exceptions which include the Sting-rays, belong to genera which have been found in the chalk. Bull-headed sharks and some of the Dogfishes are found in the Jurassic period. The Chimaeras date from the Triassic period and reached their zenith in the Cretaceous and Eocene (Norman). At this time the seas were full of weird Chimaeras of very varied form and some of large proportions. We shall endeavour to partially clothe these ancient fish with additional attributes and suggest that their huge weapons were also venomous. The modern Chimaeras are small and few in number.

It would appear that size and heavy armament tended to become obsolete, and that finally poisoned daggers are now found mostly in bony fish.

It is unfortunate for the general reader that the Port Jackson shark, formerly known as Cestracion, is now officially known as *Heterodontus Phillipi* and is the living representative of an important family, the Heterodontidae. In the fossil genera there are a number of fish which all have the dorsal fin-spine grooved on the posterior aspect while some have the lateral margins armed with a row of denticles, others have also a median row of similar denticles, and many are ornamented with enamelled bosses. The surfaces near the denticles appear to have been the site of some soft tissue which we suggest was probably of the same nature as that we have described in the living representative.

The drawing of the spine of *Hybodus* shows an anterior face convex and striated longitudinally and enamelled. The posterior aspect has a median ridge with two rows of denticles separating two roughened surfaces which are slightly concave. *Asteracanthus ornatissimus* is hollow like the preceding and is about ten inches in length and is marked by enamelled tubercles arranged in parallel rows on the convex anterior



D E

C A

FIG. 30. *Hybodus* (Hybodontidae). *A* Five-eighths natural size from a specimen B.M.Nat.Hist. The hollow spine is enamelled and longitudinally ridged on its anterior convex aspect. The posterior aspect presents a median ridge with two rows of denticles separating two roughened slightly concave surfaces. *C Pleuracanthus* (Pleuracanthidae). Threc-quarters natural size from specimen B.M.Nat.Hist. *P. cylindricus* from the Coal measures. There is a posterior shallow groove bounded by two rows of small denticles.

E Pleuracanthus laavissmus from the Coal measures anterior aspect and *P. elegans* from the carboniferous limestone posterior aspect. These spines are very similar to those of recent Trygonidae.

aspect. The posterior surface has a median ridge with two rows of recurved denticles which separate two slightly rough concave surfaces.

The family of Chimaeridae as typified by the modern Chimaera we have already described, and the archaic genera have similar spines. The species named *Myriacanthus* has a dorsal fin-spine long and slender, laterally compressed with sides ornamented with small tubercles. The posterior face has large thorn-shaped tubercles on either edge passing into a single row distally while the anterior aspect has a similar median row. This gives a picture of spines found in modern Chimaeras and there is little doubt that the denticles were anointed with the secretion from poison glands.

The head spine of *Pleuracanthus* must have special notice. Complete skulls and skeletons have been found. It is a shark, but some people look upon it as a forebear of bony fishes. The spines are like the sting-ray's and have a row of recurved denticles and a groove on either side which probably lodged a venomous tissue.

Chapter 22

DECORATION FOR DEFENCE AND THE USES OF PIGMENTS

This chapter will be devoted to the measures of defence which are available to a fish, the material that can be provided, and the varied uses to which this material can be put. The subject can be divided into two parts, the first which can be summed up as camouflage, in all its various forms, and the second the provision of weapons of defence, and also offence, usually rendered more efficient by the inoculation of venoms by means of these organs.

Before proceeding further it may be stated with confidence that no animal, even insects or birds, can vie with the brilliancy of the coloration of the *living* fish. The tragedy of the loss of all this beauty, is due to the almost immediate fading of colour and brilliance in death, so that only those who are situated in towns with aquaria can have any idea of the beauty of life beneath the sea. The colour of fish is due to the use of very simple pigments under the control of the nervous system; these pigments, being confined in cells of a contractile nature, can add more of one pigment and detract an amount of another according to the nervous impulses which act on the contractile tissue of the cell. But in addition to these simple means, other physical methods are employed such as optical interference in combination with pigmentation, and reflection, so as to produce the phenomenon of iridescence. These effects are obtained by the presence of other cells called iridocytes, which contain a substance called guanin, which resembles the substance of the same name in guano; and we must here note that the fish is making use of waste products of the animal economy to provide for its pigmentation. The guanin within the iridocytes is

in various forms, granules, rounded, polygonal or stellate bodies, or in flattened plates. Owing to their opacity and great reflecting power, these iridocytes can be made to produce a flat white or a silvery surface. The cells by their position can also vary the colours as they lie in the superficial layers of the skin. Both pigment cells and reflecting cells lie in two layers in the skin, one outside the scales and the other on the inner surface of the scales, and between the layer and the underlying muscles. It can be readily imagined from this elaborate arrangement of optical instruments and pigments that the possibility of varying and blending colours must be immense.

We have seen how in the eel the waste products of the chemical machinery are made use of in one case through guanin and in the other through melanin, and the process that takes place we will now compare to combustion. In fact the changes that take place in a living body after the food has been absorbed, which goes by the name of metabolism, are very similar to those that take place in a fire. In warm-blooded animals this analogy is more apt, as one of the first acts of metabolism is to produce heat. We will carry the analogy further and consider what takes place in a fire on an open hearth. If the fire has not sufficient draught, that is to say the supply of oxygen is insufficient, it smokes, and as a result soot is formed, a waste product. If wood is heated in a kiln from which air is excluded charcoal is produced and this we may compare to the sepia of the cuttlefish, and both are used by artists. If we watch our fire more closely we will at times see a blue flame burst out, this is carbon monoxide gas (CO) and it is burning to form carbonic acid gas (CO_2). Carbon monoxide is a very poisonous gas and combines with the red colouring matter of the blood so as to cause death. These simple observations show how a slightly different proportion of a vital gas, like oxygen, can profoundly modify the process of combustion, and so, in a more complicated manner, the products of metabolism vary with a slight change in a chemical formula, as shown in sepia becoming crab-poison.

Leaving the chemical aspect of pigments, the subject of pigments as a measure of protection may be considered in a little more detail. Two fish with very similar form and characteristics are the Black Scabbard fish and the White Scabbard; the first is jet black and the latter silvery. In the depths of the sea there is very little light, and a black object is almost invisible in the black-out; when a night raid is carried out the faces of the marauders are blackened to prevent reflection from the skin, so that the black livery of the Black Scabbard is a useful protective coloration. The silver of the White Scabbard is produced by the guanin of the iridocytes and this fish is not a dweller in the depths, but flashes past its enemies trusting to its speed. A flat fish lying on the floor of the sea is very frequently marked with spots or blotches of black so as to break up its outline. This is well shown in the Torpedo, one of the electric rays which has five round blotches, one behind the eyes, one on each pectoral fin and one on each side of the root of the tail.

The obliterative effects of these markings are so successful that a flat fish, a perfectly harmless member of the community, has used the same design either as an effort to make itself unobserved or to mimic the warning markings of a dangerous fish. This fish (*Lioglossina tetrophthalmia*) has two blotches at the widest part of its body, one on either side and two at the root of the tail and the fifth spot is situated on the small pectoral fin and so completes the same series as on its model, the Torpedo. Another flat fish from the Californian coast belonging to the Soleidae has a most complicated design, which consists of a closely set series of wavy dark and light lines running transversely, and they seem to represent the ripple markings of a sandy shore. Our own sole is also noted for its power of concealment and hiding itself in the sand, but it has also been noted that it has a black marking on its pectoral fin and that this fin is raised as a flag, being the only part of the fish clearly visible. The suggestion has been made that this black flag may be an attempt to copy the black dorsal fin of the lesser weever,

which is something to be avoided. The imitation of its background by the plaice and the flounder are very marked and are described in most works dealing with fishes, but it may be stated that the plaice can change its markings so as to copy a tessellated pavement, shingle, or a chess-board. The most interesting fact in connection with this phenomenon is that it appears to be under the control of sight which, by some obscure reflex mechanism, controls the neuro-muscular apparatus of the chromatophores, as the pigment cells are called.

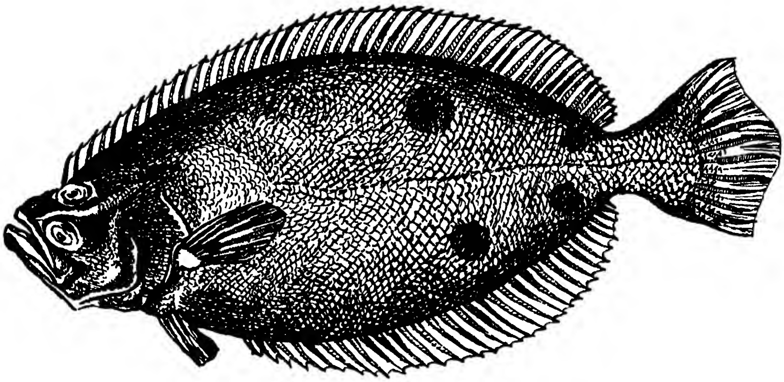


Fig. 31. Lioglossina tetrophthalmia (After Tosio Kumada)

In connection with this skilled mechanism for obtaining a replica of its background, it has been noted that the plaice has very movable eyes and that they can be protruded to a marked extent by a kind of hydraulic lift at the back of the orbits; and further I have drawn attention to the fact that its brain has very marked optic lobes, almost bi-lobed, which suggests great functional activity of the optical apparatus. The well-known dark colour of the back of a fish and the pale or white belly have been shown to be the typical example of obliterative shading, and therefore come under the category of protective decoration by means of pigments.

What do we know of the habits of the sting-ray? By direct

observation, not very much, if we except the submarine explorations of Dr. Beebe. The many species on the Atlantic coast of Mexico and the more tropical shores of Australia are very familiar to the fishermen, but they have not thrown much light on their habits. Fear takes the place of biological interest. Their diet is mostly crustacea and they are particularly partial to polychaete worms with sharp stinging spicules. They frequent sandy shores, but they are not sedentary fish and are often found swimming near the surface. Other fishes seem frightened of them and in an aquarium they are known to attack other fish and even turtles. We may be able to learn something from their coloration and the patterns that sometimes adorn their backs. The general colour is nearly always brown to yellow. There is a ray living off the southern Mexican coast with small asperities running from behind the head to the tail which ends in two small dorsal fins. Its width is greater than its length and the dorsum has on either side of the middle line a marked spot about the size of a threepenny-bit. This is exactly like the markings on the wings of a British aeroplane but there is an absence of colour. The centre is white then a ring of black, then a broader band of white, and lastly a broader band of black fading on its edges to yellow. The inclination is to say at once this is an identification mark! *Raia circularis* has markings in a very similar position, but they may have still more remarkable designs. The dark circular area has small yellow spots arranged in the position of the figures on a watch and there are central lines representing the hands. The time is twenty past six but the fish is a metric fish and there are only ten instead of twelve figures. The Cuckoo ray of English waters has markings of the same character, but the details are more hieroglyphical. The Sandy ray has also ocelli symmetrically placed, but usually six or eight in number. The question arises whether these markings are examples of mimicry or some form of obliterative design. In favour of the idea of mimicry we have seen in *Zaca Adventure* a drawing of an electric ray (*Discopyge ommata*) which

has a central ocellus, like that of the first ray we described above, with lesser but similar markings round the edge of the disc. The stimulus to the discharge is gentle pressure on the body on each side of the central ocellus. The thorny-backed ray may have mimicked the electric ray and thus obtained protection. From the pages of Beebe we gather that there are many highly coloured rays in Mexican waters; for instance he describes a Spotted sting-ray (*Urobatis maculatus*), pale creamy white with a dozen black spots on the back and in the same place he harpooned a long-tailed ray (*Amphotistius dipterurus*) 'which had concentric lines of dark colour round the rim of the disc'. Another sting-ray geometrically marked nearly had the Professor as a victim.

It will help us to come to a correct conclusion if we glance at some of the flat-fishes (Heterosomata) which inhabit the same Mexican waters. There are many species with ocelli which may possibly be examples of mimicry of rays. For example *Ranularia* has three large ocelli—one on each side of the middle line and one at the root of the tail. *Pleuro nicthys* has a median black spot surrounded with a concentric white ring, while a species of Halibut (*Lipoglossina tetrophthalmia*) has four well-marked ocelli, two on either side of the root of the tail and two more forward in position on either side of the middle line. None of these markings seems to have any relation with 'dazzle' patterns, and it would appear probable that they suggest to enemies a nasty stinging fish. We will leave it at that.

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